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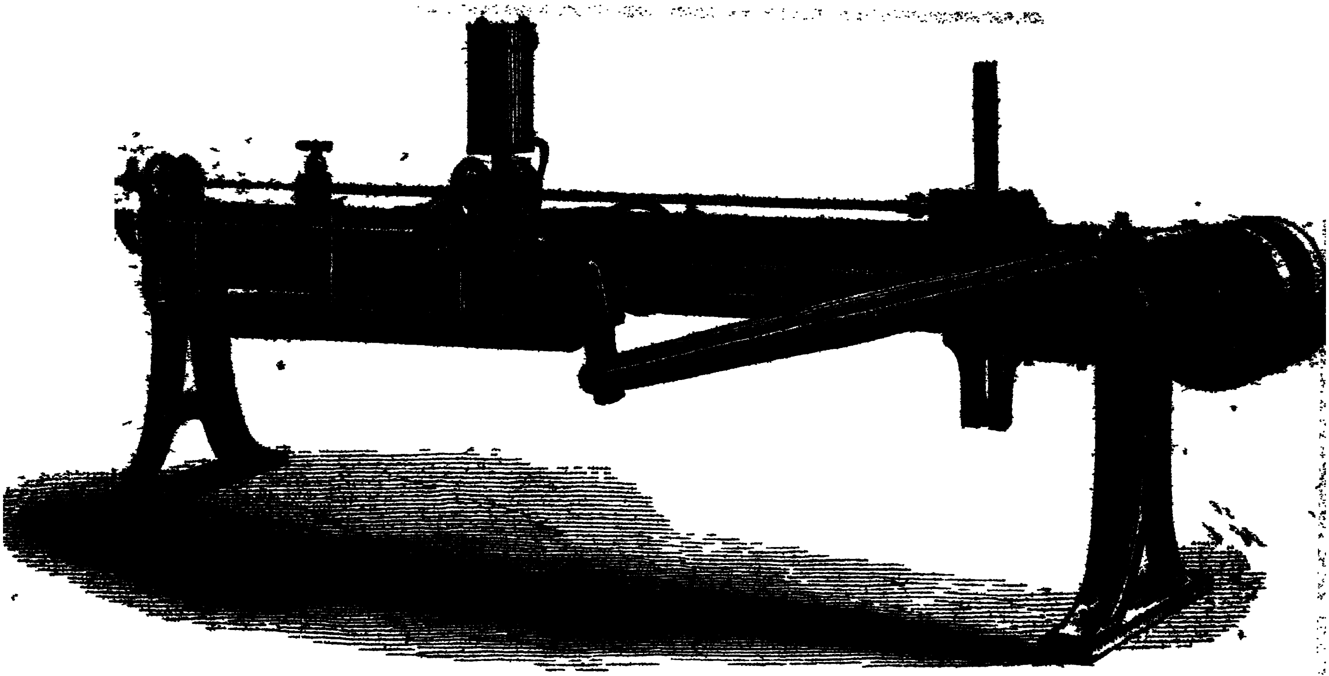

Messrs. Greenwood and Batley's Rifling Machine

THE

# MODERN SPORTSMAN'S GUN AND RIFLE;

INCLUDING

## Game and Wildfowl Guns, Sporting and Match Rifles and Revolvers.

BY

J. H. WALSH ("STONEHENGE"),
EDITOR OF "THE FIELD."
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"BRITISH RURAL SPORTS," ETC.

IN TWO VOLUMES.

VOL. II.—THE SPORTING RIFLE, MATCH RIFLE, AND REVOLVER.

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# PREFACE TO THE SECOND VOLUME.

Although, as I stated in my Preface to the First Volume of this work, I began to examine into the subjects connected with the shot gun and rifle a quarter of a century ago, I had not kept my knowledge on a level with the great progress made in the latter arm during the last few years. When Sir Joseph Whitworth promulgated the results of his experiments in 1858, I took considerable pains to ascertain their value, not only from a military point of view, but also from that of the sportsman; and for some years after the institution of the annual trial of small bores by the National Rifle Association, I carefully attended them at Woolwich, and duly reported the results in the *Field,* as well as the shooting of the selected rifle at Wimbledon. After some few years, however, they ceased to be of much value to the sportsman, and the pressure of other matters induced me not only to forego all allusion to the trials, but also to discontinue the reports of the Wimbledon Meetings. The result was that, when, after the publication of the first volume, on the shot gun, I had to turn my attention to the rifle, I found that I was several years in arrear; and it was necessary to work this up before venturing to publish the second—which must be my excuse for the long interval between them.

The first thing to be done was to admit my ignorance, and at the same time to ask for the information required from the recognised authorities on the subject. Accordingly I appealed to Sir H. Halford, Mr. Metford, Mr. Henry, Mr. J. Rigby, Mr. F. Osborne, and Mr. H. Holland for their opinions on several vexed questions; and to these gentlemen I am greatly indebted for their courteous compliance with my requests. With their aid, supplemented by a public trial, which I held in the autumn of last year, I have been enabled to satisfy myself as to all the points referred to them, and I hope my readers will be able to agree with my conclusions. In the general details of manufacture I have also been greatly assisted by Mr. Osborne, whose thorough knowledge of all matters connected with the manufacture and use of rifles has been fully placed at my disposal. To my friend "T." was entrusted the theoretical portion of the work, and his signature will, I am sure, be accepted as a sufficient guarantee for its being fully up to the mark; indeed, I may congratulate myself as well as my readers on the manner in which he has accomplished his task.

From these remarks it may be gathered that the part which I have taken in compiling this second volume has been rather that of an editor than an author, and if the results are satisfactory to my readers I can only take credit for the careful selection of reliable information from the large mass which has been placed at my disposal. In every case I have personally examined into the matter, and satisfied myself as to the truth of the statements made, so that I hold myself responsible for them. Indeed, the amount of correspondence necessary for this purpose has entailed on me far more labour than was absorbed in the preparation of Vol. I., which I wrote, *currente calamo,* in a few months.

Having thus fully explained the position which I hold in reference to the following pages, I lay them before the public, in the full belief that they merit and will receive a still more flattering reception than that which was accorded two years ago to my treatise on the shot gun.

J. H. WALSH ("STONEHENGE").

PUTNEY,
*July 3rd,* 1884.

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# THE
# MODERN SPORTSMAN'S GUN AND RIFLE.

## VOLUME II.
## THE SPORTING RIFLE AND ITS AMMUNITION.

## BOOK III.—DEFINITIONS, ETC.

### CHAPTER I.
### INTRODUCTORY REMARKS.

In pursuance of the plan adopted throughout the first volume of this work, I shall not attempt to give the history of the invention of rifling—the process by which a single projectile is made to rotate on its axis and thus maintain the accuracy of its flight though at a sacrifice of velocity. In each division of the present volume it may be necessary to make some slight allusion to this subject, but a correct and full history of the invention and of its progressive stages down to its present perfect condition would occupy far too much space, and, moreover, has already been fully given to the world by my predecessors.

Before, however, proceeding to describe the various kinds of rifles at present in use, it will be necessary to define numerous terms which must be constantly employed in their description, and also to discuss the modern theory of projectiles and other kindred subjects, which my friend "T." has kindly undertaken to supply.

# CHAPTER II.

## DEFINITIONS OF TERMS USED IN REFERENCE TO THE RIFLE ITSELF.

THE RIFLE PURE AND SIMPLE—MODE OF PRODUCING ROTATION—THE MACLEOD BULLET—THE SPORTING RIFLE—THE EXPRESS RIFLE—WHAT IS A SPORTING RANGE.

### DEFINITION OF THE RIFLE PURE AND SIMPLE, AND ITS METHOD OF PRODUCING ROTATION.

EVERY rifle is a gun made nearly in the same way as for using shot (see Vol. I., Chap. IV.), but with the interior of the barrel afterwards cut away so as to form spiral grooves of varying shapes and depths, leaving certain portions of the original tube untouched, which latter are called "lands." This grooving is effected by a machine, which is so arranged that any depth may be cut at any angle or "pitch" as it is called. The depth varies from ·100in. to ·003in. or even less, and the pitch from one turn in 16in. to one turn in 6ft.

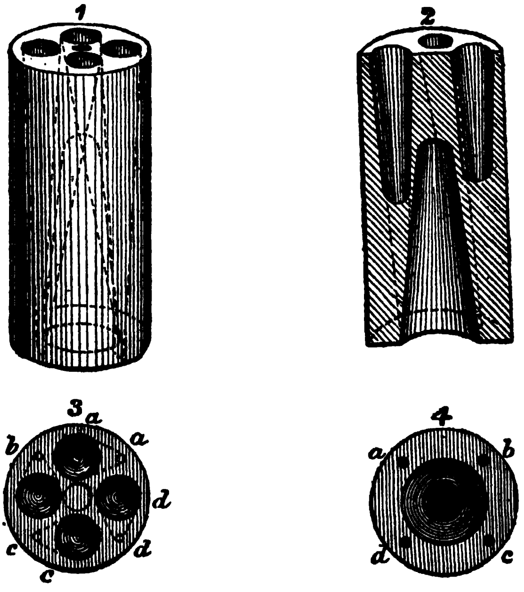
The object of this spiral grooving is to impart to a projectile (made either of pure lead or a harder alloy of that metal) a rotation on its line of flight, by which any tendency to depart from it, owing to a want of symmetry in its construction, is avoided. The arrow provided with spiral feathers is a well known example of this necessity—the rotation necessary for its true flight being effected, however, after it leaves the bow, as it passes through the air, by means of the feathers placed obliquely on its foot. The same plan has been often attempted to be carried out with a ball used in a smooth-bore gun, and to a certain extent successfully, within the last few years, by Dr. Macleod. This gentleman has introduced spiral holes of a conical shape in a leaden cylinder two inches long, and by these means he can obtain a fairly accurate flight, up to about seventy yards. This will be better understood by the following description, which was given by me in the *Field* of Nov. 8, 1879, after a careful trial of the plan.

### Dr. Macleod's New Smooth-Bore Cylindrical Bullet.

During the last twenty years we have examined a great many plans for effecting the rotation of a cylinder of lead in a smooth-bore by means of internal or external rifling, but in every case without any good result. At length Dr. Macleod, a retired Indian medical officer, residing at Yockleton Hall, near Shrewsbury, has succeeded in effecting this object by the simple expedient of making the rifled or twisted internal tubes conical, each of the four being reduced from $\frac{3}{32}$ of an inch at its mouth to about $\frac{1}{64}$ at its exit on the breech end. The opposite engraving shows the form of his bullet of the full size. It weighs $2\frac{1}{4}$oz., and is at present cast of hardened lead; but the inventor proposes ultimately to make it by pressure, so as to eliminate the chance of air bubbles in the casting, by which he thinks the centre of gravity is thrown on one side, and the ball does not maintain its line of flight, as now happens occasionally. Behind the ball he places a thick wad of indiarubber, which effectually prevents the gas escaping through the four tubes, and also from entering the conical cavity at the base, which is intended to throw the centre of gravity forward.

Fig. 1 is a perspective view of the ball, showing the four openings of the tubes in its fore end and their conical form as indicated by the dotted lines. Fig. 2 gives the section of the same, showing also the conical cavity in the base. Fig. 3 is a plan of the fore end, *a a*, *b b*, *c c*, and *d d*, each indicating, by dotted lines, a rifled or twisted tube, and the amount of obliquity or twist in it. In Fig. 4, the four small openings of the tubes are shown at *a*, *b*, *c*, and *d*, together with the large conical cavity intended to lighten the base.

About six weeks ago we ourselves tried a few of these balls at 70 yards with 2½drs. of powder, and made excellent shooting with them; but the trial was not sufficiently extended to induce us to report it. Last Monday, however, Dr. Macleod obtained the use of Messrs. Holland's range at Kilburn, and also the assistance of his "regulator," whose skill both with the shot gun and rifle is quite A 1. Messrs. Holland had in the interval re-bored the gun used chiefly by Dr. Macleod, which is a heavy single-barrelled 12-bore, weighing about 8lb.; but we also tried several shots from a double-barrelled 12-bore, with nearly equally good results. From these guns a series of shots were taken with various charges of powder, the conclusion arrived at by all present being, that at 70 yards 2½drs. will suffice to give excellent shooting, but that 3drs. are required for 100 yards, and that beyond that range the shooting is rendered wild and unreliable. Having settled these points by sundry experiments, we determined to fire the last remaining seven balls with 3drs. of powder from the single barrel at 100 yards, the result being that six out of the seven shots pierced the wooden target screen, each with a perfectly round hole, and all within a square of 4in.; while one of them (the fourth) was



Figs. 1 to 4.

7in. from the centre of the square, and had turned over sideways, making a hole corresponding with its length in the wood. As to penetration, the ball pierced nine and a half 1-inch planks of the same wood as was used in Messrs. Holland's trial, recorded in the *Field* of Nov. 22, 1879. Here, then, we have shooting from a smoothbore equal to that of an Express rifle, with a ball nearly double the weight of the spherical ball which must be used in the same bore, whereby, of course, the shock given would be greatly increased; but, whether or no the velocity would be sufficient for an elephant's skull we do not pretend to say, as with a spherical ball in a 12-bore it is admitted that 3drs. of powder are insufficient. In any case, Dr. Macleod's invention is of the highest interest, and opens out problems to be solved, not only with regard to sportsmen, but also for big guns in war, wherein the rifling seems now to be the main difficulty. The balls used fitted loosely but accurately in the gun, and the recoil is about equal to that of an ordinary charge of powder and shot.

Messrs. Greenfield and Son, of Queen's Buildings, Pancras-street, London, supply the bullets wholesale, and Messrs. Bland, of 106, Strand, are the retail agents.

In practice, however, it has been found that the ball must fit the barrel so exactly (neither too tightly nor too loosely) that it is beyond the scope of the ordinary sportsman, and hence it has not been at all generally adopted.

But it has been said by many good sportsmen that a smooth-bore may be made to shoot spherical balls so truly that for many kinds of game it is to be preferred, on account of the greater velocity, and consequent increase of smashing power. They allege the accuracy of the duelling pistol (which was a smooth-bore) in support of their opinion, and some even go so far as to assert that up to 50 yards, a six inch circle may be invariably hit by a spherical ball from an ordinary 12-bore gun if properly bored. As to the duelling pistol, there is no doubt that it could snuff a candle at 12 yards, but beyond this distance it was never tested, and this is certainly not the range which a sportsman requires. If, however, the six inch circle at 50 yards could be depended on, I should be ready to admit that for large game it is a most useful weapon; and with this view I have repeatedly tested smooth-bores by various makers, but the trial has invariably ended in disappointment. Sometimes the first or second, but oftener further on in a short trial, a wild shot has occurred; and of course this wild shot may be the one to cost a sportsman his life, when charged by any kind of large game. The slightest defect in the ammunition or in the muzzle of the gun, will bring out this defect, the result being a very much wider circle than six inches, as was exemplified in the public trial of rifles recently carried out by me at Putney and Nunhead, to which I must refer my readers in a future chapter.

As I have before remarked, this superior accuracy of flight is not obtained without some sacrifice in bullet speed (shown at short ranges chiefly), but it is much more than compensated for, even at ordinary sporting distances by the great gain in accuracy of fire; and at anything approaching long ranges, no comparison of work done with the smooth bore is possible from its extreme inaccuracy. This rotation of the projectile during its flight is rendered necessary by the fact that it is practically impossible to obtain an absolutely symmetrical and concentric missile—that is, one in which the centre of gravity is coincident with its centre of figure; even with the simplest form of projectile, the spherical bullet, this cannot be obtained. Consequently, when discharged from a smooth bore, and exposed to the resistance of the air, an oscillating or "wobbling" flight is produced, causing a deviation from what should be the true path, and this deviation rapidly augments in proportion as the range increases.

With a conical or elongated projectile, as the disagreement between the centres is more marked, the necessity for the rotation given by rifling is even more imperative. Thus it will be seen that the main feature of the rifle is its power of overcoming the defects of the projectile, by imparting to it a definite rotation, and thereby immensely improving the accuracy of fire. That this useful property of rifling was an early discovery in the history of small arms there is no doubt; but, in the absence of perfect mechanical appliances for producing true and well-finished barrels, the full value of the invention could not be realised; and, as a matter of fact, it is only during a very recent period that it has been found possible to produce rifled barrels free from such irregularities of construction as materially impaired their performance. This will no doubt account for the small estimation in which the rifle was generally held for a long time subsequent to its discovery.

## Constitution of the Sporting Rifle.

By this term is of course to be understood any rifle, whether single or double, made with the intention of killing any kind of game, whether at long or short distances from the sportsman. It includes, therefore, all the following varieties—viz., the rook rifle, either single or double, with so small a bore as ·220 to ·300; the various medium bores from ·400 up to ·577, which are now generally made up as double rifles, and are used, as we shall hereafter see, for various purposes with conical balls; larger bores from 16 to 12 gauge, generally used with spherical ball; and still larger bores, from 10 to 4 gauge, which are always used for large game, with heavy charges of powder and spherical ball.

These various kinds of sporting rifles may be divided into (1) rook rifles, (2) small-bore rifles for long range shooting; (3) small-bore rifles confined to 150 or 200 yards, and usually called Express rifles; and (4) large bores for big game. But, further than this, the term admits of several definitions varying more or less in detail; but we must take a leading type of sporting rifle as the groundwork for the most obvious illustrations of this class of arm. That excellent writer, Capt. James Forsyth, in his book on "Sporting Rifles," * gives a tolerably good description of what a model sporting rifle should be, as then understood, to suit the requirements of a kind of sport of considerable importance, and with which he was personally most familiar. The then state of development arrived at by the rifle manufacturers of the country generally is well illustrated in his remarks, unfortunately too long for quotation in their entirety; but his summary (arranged in tabular form on page 16), eliminating those points relating to muzzle-loaders as obsolete, and those treating of large calibres as partly so, will be found to cover and include the characteristics of a large and important class of sporting rifles. His table is arranged as follows:

(1.) Moderate weight (not exceeding 9lb. unless for exceptional purposes.)
(2.) Moderate recoil.
(3.) Sufficient accuracy at sporting ranges.
(4.) Sufficient penetration at sporting ranges.
(5.) Lowest possible elevation at sporting ranges.
(9 and 10.) Moderately short barrels and general handiness and simplicity.

We here find the qualifications of the average sporting rifle fully defined, and nothing so satisfactorily fulfils Forsyth's conditions as that system of rifle, foreshadowed, it is true, in his book, but completed and to a great extent perfected since that time, namely, the so-called "Express" rifle (of average power and calibre). Here we have a term requiring further

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* "The Sporting Rifle and its Projectiles" (Smith, Elder, and Co., London, 1867), pp. 3 to 18.

definition, a task of some difficulty on account of the wide scope and numerous variations of the Express system, as we shall presently see.

### WHAT CONSTITUTES AN "EXPRESS" RIFLE.

This term "Express" may be understood to mean a rifle of ordinary weight and small calibre, firing a large charge of powder and a light bullet, thus delivering the latter at a high rate of speed. This bullet is so constructed as to possess the power of expanding on impact, and thereby making as superficially large and severe a wound as the non-expanding bullet of a much larger calibre. This arrangement further admits of considerable accuracy and a flat trajectory up to a limited range, generally considered sufficiently extended for sporting purposes. It will hereafter be seen that every requirement which a sporting rifle should have for ordinary work is to be found in the Express type of rifle and ammunition; but the definition depends much more upon the proportions of the charge than on any marked peculiarity in the rifle itself.

In order clearly to settle the meaning of this term, I applied to the following gentlemen, whose reputations stand at the top of the tree in the estimation of modern sportsmen, for their several opinions, viz., Sir H. Halford, Mr. Metford, Mr. John Rigby, Mr. A. Henry, Mr. H. Holland, and Mr. F. Osborne. All of them have responded to my appeal in the most kind and careful manner, and I need scarcely say that a mass of highly valuable information is thus afforded, as will be evident to my readers on a careful perusal of the following pages. The opinions originally given were printed and circulated among these experts, who have severally criticised each other's remarks.

## OPINIONS GIVEN ON THE MEANING OF THE TERM "EXPRESS."

### 1.—By Mr. METFORD.

When dangerous game is not to the front, it is a question whether a moderate load (not quite Express) is not better, from its greater accuracy and less noise, though less smashing in its effect—say 90gr. C. & H. No. 6, with 360gr. bullet.

Dangerous game is usually close enough for accuracy to be of less importance; but for other game, which may be a fair distance off, speed is valuable—for we must never lose sight of the fact that smashing power increases in about square ratio of speed, not merely with the speed.

### Definition of Express.

I agree with Sir H. Halford that about 1600ft. per sec. may be called the lowest Express rate, which I find will require, in usual bores, and usual length of barrel, about 1 of powder to 4 of lead (by weight).

### Standard Range for Trajectory.

All my stalking friends tell me that nearly all shots are under 100 yards. If so, I should think 100 yards would be better than 150 yards, when trajectory height is to be the standard: but I myself prefer initial speed. I think it puts up more satisfactorily: *but I am a scientific gunner, and not a stalker.*

### Light Bullets.

I think Purdey (years since, in muzzle-loading times) got up the greatest speed with the lightest bullet (270gr.)—a double belonging to Sir H. Halford. It shot very prettily at 100 yards; but at 150 yards and 200 yards its falling off, both in speed and accuracy, was so serious that I determined on a more stable weight (360gr.); as, although the greater number of shots are within 100 yards, yet a stalker does at times chance a long shot, and he dearly likes to do it nicely. If I took to stalking, I should not use a bore over ·420, as a 360gr. bullet in this narrower form would fly far truer, and lose less speed. I see some even go for ·500-bore for Expresses. All I can say is, that I have never yet seen, or authentically heard of, a rifle of ·500 using a 350gr. bullet shooting *well* at 100 yards.

### DEFINITION OF SHOOTING "WELL" (see above).

I mean by "well" that ten shots out of a single-bore at 100 yards should be covered by the fist, not too tightly doubled up—say half doubled up—this being a sort of "rough and tumble" gauge of Express shooting at 100 yards. Now, one of my B.L. match rifles, in the hands of such a man as Major Young, will strike a two-shilling piece at 100 yards every time; but the short bullet in vogue for Express rifles is so subject to muzzle error that it will not start so accurately from the bore as the long match bullet. This is why I should go in for ·420. Sir H. Halford even favours the ·408, which he has been working with very much lately; and very possibly it will do very well. One I had made through Mr. Deeley (Westley-Richards and Co.), at Sir Henry's desire, ·408—a miniature, in fact, of my military rifle in all respects—shoots beautifully up to 2000 yards (if calm), and at 100 yards like a match rifle.*

I myself do not think a ·500-bore should carry less than 130gr. powder, and 425 to 450gr. lead, which would give about 1730ft. speed; but is unnecessarily powerful for deer. Even tigers do not require ·500-bore, if I may depend on Sanderson, who speaks with great care as to the value of life to sportsmen.

### ON TRAJECTORY AND FALL COMPARED WITH SPEED.

The values of the different speeds in trajectory are so little that they do not seem so striking as speed statements are—*e.g.*:

100 YARDS RANGE
(not allowing for retardation of air).

| | | Fall in 100 yds. | | Trajectory. |
|---|---|---|---|---|
| 1600ft. | initial will give about | 6·78 inches | ÷ 4 = | 1·7 inch nearly. |
| 1700ft. | ,, ,, | 6·01 ,, | ÷ 4 = | 1·5 ,, |
| 1800ft. | ,, ,, | 5·35 ,, | ÷ 4 = | 1·34 ,, |
| 1900ft. | ,, ,, | 4·8 ,, | ÷ 4 = | 1·2 ,, |
| 2000ft. | ,, ,, | 4·34 ,, | ÷ 4 = | 1·09 ,, |
| 2100ft. | ,, ,, | 3·9 ,, | ÷ 4 = | 1·0 ,, |
| 2200ft. | ,, ,, | 3·5 ,, | ÷ 4 = | 0·9 ,, |

for you see, by the above, that the whole difference is (between 1600 and 2200) only 0·8 of an inch.

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* Sir Henry put eighteen out of twenty shots at this range of 2000 yards in a vertical of 12ft. by 9ft. wide, without a rest.

### 2.—By Mr. RIGBY.

The Express has no definite meaning at present. It is applied to all rifles having a tolerably high initial velocity, and fitted with a projectile more or less hollowed out; sometimes also to rifles fitted with solid projectiles, if only the initial velocity be high.

The qualities which *ought* to exist in an Express rifle are low trajectory, to render judging distance easy; and sufficient remaining velocity in the bullet to flatten it out more or less, and so expend its entire energy on the animal.

A rifle with a very light hollow bullet may be Express (as above) up to 100 yards, but not so at longer ranges, the initial velocity of the light bullet being rapidly lost. A spherical-ball rifle even may for 50 or 100 yards have the same mean velocity as such an Express; but, owing to its shape and solidity, the bullet would penetrate without expanding sensibly, and so would miss the second quality of the Express.

### Final Definition.

Any rifle calculated to send an elongated bullet which will flatten out more or less on striking flesh, and so expend its entire energy on the animal aimed at, and whose trajectory to 200 yards does not rise more than 12in. above line of aim, might be called an Express.

### Miniature Express.

Rifles carrying smaller and lighter bullets which flatten as above and fulfil the conditions as to trajectory might be called Miniature Express rifles.

### Magnum Express.

Those rifles which carry bullets heavier than 400gr. and fulfil other conditions might be called Magnum Express.

### Rate of Spiral.

It is not proved that a slow spiral or an increasing spiral is necessary or even favourable to the generation of Express velocities.

### Bottle-shaped Cartridges

Will develope higher velocity from moderate charges than cylindrical cases—and also exert more strain on the action.

### POINT BLANK.

This phrase has no definite meaning, and is interpreted so loosely by different authorities that it ought to be abolished, and some measure of the trajectory necessary for sporting rifles substituted. Why not fix 200 yards as a standard range, and class rifles by the height above line of aim to which bullet rises? This can be computed without screens.

## 3.—By SIR H. HALFORD, BART.

### EXPRESS RIFLES.

About thirty years ago the only sporting rifles known were those constructed to carry a round bullet propelled by a light charge of powder and having a slow spiral; but, with the invention of a plug bullet, a fresh departure was taken.

In 1859 Mr. Purdey, the well-known gunmaker, made for the late Lord Henry Bentinck three double rifles of 40-bore, taking 4dr. of powder; and the same year rifles of the same calibre for Capt. (now Col.) Bateson and Capt. the Hon. W. Wyndham (now Lord Leconfield); and also one of 50-bore, taking 4½dr. powder, for the late Sir St. George Gore. Although previously Mr. Purdey had been increasing the powder charge, these rifles must be considered as the first of the class now known as Express—a term believed to have been first used either by the late Lord Henry Bentinck or by Lord Leconfield. In 1864 Mr. Purdey made for the late Lord Henry Bentinck two double rifles of 80-bore, taking 4dr. of powder; and in 1865 an experimental barrel of less than 100-bore, taking 4½dr. With this rifle Morrison, his lordship's stalker, killed seven hinds, and sent the bullets, which he recovered, to Mr. Purdey. They were as flat as a shilling, and about the same thickness through the centre, the edges being quite thin and jagged; but the rifle was not adopted, as the fouling was excessive. In 1865, 70-bore rifles, ·408 of an inch, taking 4dr., became general. Mr. Purdey also first introduced the bullet with a small hollow in front for the purpose of expansion, which must not be confounded with that of General Jacobs, who was the first to introduce the very rapid twist and the hollow front for a shell.

The system of heavy charges of powder with modifications as to bullet and bore was at once taken up by most of the leading gunmakers in this country, and is that most generally in use at the present time both in the deer forests of Scotland, and for soft-skinned game, as bear, tiger, and all kinds of deer, in India. It is also making steady progress in the United States of America.

As yet there seems to be no absolute definition of what constitutes an *Express rifle*, but I think it would be well to class under this head all those in which the initial velocity reaches 1600ft. per second; and, as it has been found roughly that this speed will be attained when the weight of the projectile is not more than about four times the weight of powder used, we may take four of lead to one of C. & H. No. 6 powder as a fair definition of an Express, irrespective of calibre of rifle.

The function of the hollow front to the bullet, used without any explosive filling, is that on striking an animal the bullet shall open out and become like a mushroom in shape—thus delivering the whole of the work done by the powder into the beast fired at; for the Express bullet does not as a rule pass entirely through an animal.

Those who have used these rifles are well aware of the fearful wounds made by them, due to the meat being driven aside so forcibly as in its turn to act destructively on the adjacent parts; but many are not aware that this destructive power is gained at the expense of accuracy, and that, after a proportion of about three of lead to one of powder, the accuracy of a rifle begins to fall off somewhat rapidly.

Having given a general idea of Express rifles, it will be well to describe a little more fully the proportions of those commonly in use, and for this purpose it will be convenient to give the calibre in fractions of an inch, and the weights of powder and bullet in grains.

The first to notice is—

Calibre ·500; powder 165; lead 350; initial speed about 2000ft. per second. Should shoot into six inches at 100 yards. Suitable for tiger, bear, and large deer.

2nd. ·460 and ·450; powder 123; lead 360; initial speed about 1830 for a 30-inch barrel. Should shoot into four inches. Suitable for bear, tiger, and all kinds of deer.

3rd. ·460 and ·450; powder from 110 down to 90; bullet 360. The lower charge would give about 1600ft. per second, and is exceedingly accurate. It will shoot into three inches at 100 yards. Suitable for all kinds of deer.

4th. ·410 and ·400; powder 90; bullet 350; speed 1600ft. per second. Will shoot into about 2½ inches at 100 yards, and in my opinion is the pleasantest and best rifle for deer; at the longer ranges, too, it is more accurate, and retains its speed better than the ·450 or ·460 bullet, and therefore has a flatter trajectory and more power. It has also another advantage, in disturbing less ground by its lighter report. As most game is shot at distances under 120 yards, I think it best to have a rifle sighted to shoot 3 inches high at 100 yards. If this is done one can be sure of a good hit up to 140 yards, by always aiming about the same place.

Up to 1859 Mr. Purdey used 2½dr. in 40-bore, increasing spiral, final pitch, I think, 1 in 4ft., picket bullet with wings. When he increased his powder charges, he still used the picket bullet, and, I believe, all through with his smaller gauges; and only dropped the wings when he took to breechloaders. The 40-bore, 2½dr., made most extraordinarily good shooting. The trajectory was of course high. The drop from 100 to 200 would be 2ft., but the fastest Express is 16in. People are deceived into thinking it less, from the habit gunmakers have of sighting their rifles 6in. or more high at 100 yards. This, at 200 yards, will make a rifle shoot only 4in. low at 200 yards, and then they claim that there is only a drop of 4in. from 100 yards to 200 yards. I do not like this plan, as more deer are shot at under 100 yards than over, and more are missed over than under. Moreover, it is almost impossible to make a clean head shot at from 50 yards to 100 yards with an oversighted rifle. This was one of the causes of bad shooting at the Boers with the Martini at close quarters.

The prints of bullets you send me are just what I have experienced, they are so acted on in rifles that are not Express.* A winged ball would be equally an Express if its speed was high enough. I should not of course consider 2½dr. in a 40-bore an Express; but 4dr. would give sufficient speed.

I think Mr. Osborne is wrong in saying anything about solid or hollow bullets in the definition. It is almost impossible to make a rifle shoot with both bullets to the same sight, on account of their different weight. If the solid is shorter to bring it to the same weight they will do so; but the Express bullets are most of them so short now, that if shortened accuracy is lost. I think the 360gr. bullet far more effective than the 260gr. It is steadier, more accurate, and gives a more crushing blow.

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* This refers to the engravings of solid balls expanding into a mushroom form when shot into a sand bank, published in the *Field* in 1858.

### 4.—By Mr. HENRY.

As promised in mine of the 26th inst., I now send you some information bearing on the origin of what are known as "Express" rifles.

My first attempt in the direction of making such a weapon was in 1853, when, at the request of the late Robert Cheape, Esq., of Wellfield and Strathtyrum, I made a number of experiments with the view of producing a rifle that could be used with a Standard backsight only, at all distances up to 150 yards, dispensing with the leaves for intermediate distances that had to be employed with the rifles then in use. In carrying out these experiments, I had under consideration the gauge of the barrel, the mode of rifling, the construction and component parts of the bullet, the lubrication, and the powder charge.

My early experiments were made with a ·451 gauge muzzle-loading rifle and 3½ drachms of powder, and, though not quite such a success as regards lowness of trajectory as had been anticipated, yet the results were so much beyond anything that had previously been heard of that I named these rifles "Low Trajectory."

Having altered the spirality of rifling and increased the charge of powder to 4½ drachms, the results were greatly better—indeed, nearly equal to that obtained with the most improved rifles of the present day.

In the original experiments carried out at Mr. Cheape's desire, I used bullets of pure lead; but on these being tried practically against deer in the forest, they were found to be objectionable, the wound made being very large, consequent on the distortion that took place in the bullet on striking the animal. I then used lead slightly hardened with tin, which gave increased penetration, a lower trajectory, and did not make quite such a large wound. A farther change in the shape of the bullet reduced the friction forward, and aided further in lowering the trajectory.

During the time or part of the time that I was carrying out the experiments, it is very probable that Mr. Purdey was similarly employed, as in the year 1855 or 1856 he brought out a rifle which he called the "Express Train," and the word "Express" has since been pretty generally used in referring to low-trajectory rifles. I would not therefore like to claim the entire credit of being the first to introduce these rifles, as, if Mr. Purdey was working them out at the same time, he is entitled to a share of the credit. I may say that when I made my experiments I had not heard anything of Mr. Purdey's, and, so far as I know, no other maker had brought out a similar kind of weapon at that time.

With regard to the minimum muzzle velocity that should constitute a rifle an "Express," I agree with you, that it should not be fixed at less than 1600ft. per second. With the ·450 rifle, 5 drams of powder, and my ordinary Express bullet, a velocity of about 2000ft. is developed, which I think is about the maximum that can be obtained.

I do not know whether you will be dealing with anything but sporting rifles, but may just mention that I was very early in the field with a long range-rifle. In 1852 I carried out some experiments in presence of the late Mr. Ellis, M.P., and Capt. Horatio Ross, at Bells Mills, Edinburgh. The rifling which I used was three shallow segmented grooves, and the trials were so satisfactory that the results were communicated to the War Office, and in 1853 the Enfield rifle rifled, on the same principle, was produced.

### 5.—By Mr. F. OSBORNE.

If we look back at the sporting rifle for dangerous game about and a little before 1870, we may be enabled to realise most of the qualifications a perfect Express rifle should have. At that period sporting rifles were mostly of large calibre, ranging from 24 to 12 bore as a rule, and constructed to fire either a spherical ball with a slow pitch of rifling, or an explosive shell, or an elongated bullet with necessarily a more rapid spiral. These systems were found to be unsatisfactory; the former, though giving a flat trajectory to about 80 yards, required elevation beyond that range, and in the matter of accuracy of diagram it was far from perfect. Its killing powers, unless used with charges of powder not to be borne in *portable* rifles, led to the adoption of the explosive shell—a costly, complicated, and in many points an unsatisfactory arrangement. The elongated bullet rifles, with their quick turn, were much more accurate even at considerable distances, and in this had a marked superiority over their rivals, but were much inferior to them in the matter of trajectory, requiring an elevation for every 50 yards; in killing power, in most cases, they were deemed inferior to the rifles using the spherical ball, unless treated in exactly the same way.

The term "Express," and the kind of rifle to which it applies, owe their existence mainly to the description of bullet used—a bullet so light as to admit of enormous powder charges being burnt behind it without producing an unbearable recoil even in easily portable rifles—a bullet that can be used in small calibres without diminishing its killing power, retaining all the flatness of trajectory and accuracy of diagram peculiar to those calibres, and yet, on striking the game, capable of inflicting the severest wound in consequence of its change of form upon impact, and an expansion exceeding in size and lacerating power the old 12-bore ball.

We may here remark that these old systems of rifles would have been much more effective if their weight could have been increased; this rather points out the first consideration to be attended to in defining a model Express rifle—its weight. No Express rifle can be worthy of the name as a thorough all-round weapon, combining the greatest destructive power with general handiness, that exceeds say at most 10lb. Why? Because the military authorities, after immense experience, have concluded that 9lb. is sufficient for the soldier's rifle; so, taking the average sportsman, his physique and his impedimenta, into consideration, the most we can allow is an extra pound. This point conceded, we can proceed to dispose of the remainder by insisting upon the initial velocity of the bullet being not less than 1800ft. per second, more if possible; a rifle that does not approach this, the key of the Express system, places itself out of the scope of our investigations. Why? Because unless such a bullet starts at such a velocity, or thereabouts, upon impact when fired from the extreme sporting ranges its striking force would be so impaired as to prevent the complete change of form, &c., so characteristic of the perfectly acting Express bullet.

The next point to be considered is the trajectory. It will be generally acknowledged by sportsmen that to be relieved in great measure from the trouble of judging distance and adjusting sights, is of the greatest value in the field; no rifle enables us to dispense with these embarrassments so completely as the Express, and this only to a partial extent, and to a moderate range, which may be taken for its extreme limit as 150 yards. Any rifle capable of being used at all ranges up to that distance with one fixed sight and aim, without the vertical deviation from bullet drop seriously impairing the value of its diagram, must exhibit one of the finest qualities of the Express, provided that no undue decrease in its destructive power, or increase in its recoil, be caused by the means taken to obtain this excellent feature in a sporting rifle.

I may illustrate my views on the trajectory of a typical Express rifle when I say that from 50 yards to 150 yards there should not be a greater bullet drop than 5in. or thereabouts.*

As to accuracy of fire, the conditions already enumerated as essential to the Express are considerably at variance with those that should exist in a rifle intended to give a high degree of accuracy; still, for a limited number of shots the Express rifle is fairly accurate. No conditions of sport could arise where any *number* of consecutive shots would require to be fired; and even with the heaviest charge used, seven or eight shots can be fired in succession without a serious amount of error becoming apparent.

My idea of the standard of accuracy necessary to an Express rifle is, that it should place its shots in a 6in. circle, or thereabout, from the 150 yards range when fired under fairly favourable conditions. It should be here noted that by ringing the changes on the constituents of the Express system, either the calibre, weight of bullet, charge of powder, &c., rifles can be constructed to give special prominence to either one or other of those features whose judicious combination result in the production of a perfect arm: thus, the power of the rifle may be developed at the expense of its recoil, accuracy, and trajectory; or its accuracy may be augmented by the sacrifice of a portion of its power, &c.

To sum up: An Express rifle should be of moderate weight; certainly not exceeding that of the service rifle by much more than a pound. The recoil of the rifle should be measured by the same standard, and should not much exceed that of the service arm. The rifle must fire a bullet capable of considerable and ready expansion on impact, producing a severe and dangerous wound, but should also fire a solid bullet, giving great penetration. If possible, the sighting for which at, say, 100 yards should agree with that of the Express projectile: the initial velocity of which should be

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* Note by Sir H. Halford: Impossible to get.

1800ft. per second, or thereabout. The trajectory should not show a greater bullet drop than 5in., or thereabout, from 50 to 150 yards. The accuracy should not give a much wider group than one of 6in. diameter when fired from the 150 yards range. Of course, in the matter of trajectory and accuracy we should take as an illustration the performance of a *single* rifle, for obvious reasons; though, when perfectly regulated, the double rifle is not so far behind the single as may be generally believed. I am aware that in some of the figures by which I have attempted to illustrate the work of an Express rifle, I am somewhat behind the degree of excellence already supposed to be arrived at by some advanced rifle makers, but I prefer that it should be so.

### 6.—By Mr. H. HOLLAND.*

A minimum of 1600ft. per second initial velocity, and a maximum of 2000ft., would probably include all kinds of rifles called Expresses. The proportion of powder to lead required to produce these velocities would range from 1 powder to 4 lead for the lower velocity, to 1 to 2 for the higher.

I consider for the ordinary bores, say ·450 and ·500, the velocity of from 1700ft. to 1800ft. per second is that most likely to give the best results, combining great accuracy with flatness of trajectory. To obtain these results, I use a charge of not less than 1 powder to 3 of lead, with a minimum of 4dr. powder in the ·450 bore, and 5dr. in the ·500 bore. With these charges we have been able to obtain great accuracy at the longer ranges, at which many Expresses fall off very seriously.

Such a high velocity as 2000ft. per second can only be obtained by using very light bullets and very heavy charges of powder, always at the sacrifice of accuracy and penetrating force.

There is some difficulty in getting a definition of "Express" by either initial velocity or proportion of powder to lead, without at the same time fixing a minimum charge of powder. For example, if initial velocity only be taken as the standard, a very short light bullet, fired with a moderate charge of powder, giving a high initial velocity, might be used, which would so rapidly lose speed that at 150 yards the *fall* would be so great as to take the weapon altogether out of the Express class.

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* These remarks have been considerably altered and added to since they were first issued.

A charge of 1 powder to 4 lead is sometimes considered an Express rifle charge. Under certain conditions this may be correct; but it cannot be taken as a gauge of an Express unless a minimum charge of powder be given at the same time. A low trajectory is only one of the *desiderata* of a satisfactory sporting rifle. I consider that the most important features are—(1) accuracy of shooting, and killing power; (2) low trajectory; (3) such freedom from fouling as will allow of a series of shots being fired without any falling off in accuracy.

1. ACCURACY.—Not only should an Express make a close diagram at short ranges, but, if properly constructed, and the bullets and charges correctly proportioned, this should be obtained even with a double-barrelled rifle at 150 and 200 yards. A ·450 deer-stalking Express should place a series of ten shots, at any rate, into a 6in. square at 150 yards.

2. TRAJECTORY.—It is pretty generally known that a good Express will give a trajectory of about 3½in. to 4in. up to 150 yards—which is practically all a sportsman can desire upon this point. Complaints are often made that Express rifles shoot high. This is frequently the fault of sportsmen themselves, who demand the impossible, viz., a flat trajectory to 200 yards—a demand constantly being made. The result is, that some makers, to meet this demand, sight the rifles for these gentlemen with the first sight cut to the 200 yards range; consequently they shoot many inches high at those ranges at which perhaps most game is killed, viz., from 50 to 100 yards. I consider that an Express should be sighted correctly at 100 yards—certainly not high; as I have always been informed by many of the best and most experienced sportsmen, that a large proportion of the game missed is lost through shooting over the object. Even when a rifle is correctly sighted at 100 yards, there is always the risk of the sportsman not taking a sufficiently fine sight, or not getting down to the bottom of the notch of the back sight, or even of the rifle "jumping" if rested upon any hard substance. How much greater, then, is the risk of this if the rifle is sighted to shoot some inches high at this range!

3. FREEDOM FROM FOULING.—As to this point, all that is required is that the rifle shall not need wiping out, in order to keep up its original accuracy, for ten successive shots.

## REMARKS ON THE ABOVE "OPINIONS ON EXPRESS RIFLES."

### BY MR. METFORD.

Regarding the question of what should be reckoned as Express speed, I think your 5in. really as good as need be. All I wanted to prove was that, by experiment, I got this within a fraction of an inch by 4 lead and 1 powder, which gives about 1600ft.

You see there is (at least to my mind) a real practical value in thus making it a proportionate affair of powder and lead, for, in many matches in India, I believe, there are prizes for Expresses; of course, Express loaded. Now, if either initial or terminal velocity, or, again, the drop, whether between 100yds. or 150yds., or from initial line, be taken as standard, who is to prove whether Express was or was not used? Few people have speed instruments, and the amount of wrangling over drop would be interminable; but anyone can readily and unmistakably test the proportion of powder and bullet.

You say, "what is the sportsman's outside distance?" I am told by my friends, Sir H. Halford and H. Evans, of Jura Forest, that most shots are taken within 100yds. I have poured into my ear wonderful shots at 200yds. and more, but I take it that no one need bother about such a range; 150yds. is about the general extreme. Your letter puts this question:

What terminal velocity at 150yds. do you consider would correspond with a drop of little more than 5in. between 50yds. and 150yds.?

Do not you mean between 100yds. and 150yds.? Your paper of Feb. 20, 1883, says, p. 2 (nearly at end), 5in. from 100yds. to 150yds.

I see that the charge I used in the experiments which guide me in this matter would give about 1600ft. per second, and at 150yds. give 1225ft. per second.

My trajectory drawing tells me as follows: Sight set true for 100yds. at 50yds., bullet about 1¾in. nearly above line at 150yds., about 5in. below, weight of bullet, 360grs.

Possible error would be limited to something not worth recording, but say ¾in. of the latter; not that I have any belief that I have made a ¾in. error. My speeds were taken, not from computation from mean speeds, as taken by cutting two wires, or breaking two connections, but by a ballistic pendulum, the special idea of which was suggested to me by my friend William Froude some years since, and the design of which I worked out myself, and which had his approbation. It is so delicate that it will show the variation in speed caused by putting two wads behind the bullet instead of one.

With it I get actual velocities right off; and this without there being any necessity for striking the pendulum in its axis, which was the old trouble. It is a peculiarly charming instrument for ascertaining actual striking speeds as one retires back and back.

I have been now using it for the last twenty years, I think it is, and I believe it to be most decidedly superior to any of the instruments now in vogue for small arm work.

## By Mr. HENRY.

I still adhere to the opinion that no rifle should be designated "Express" which does not give an initial velocity of 1600ft. This is the minimum, but of course the greater the velocity that can be developed the better, provided accuracy can be maintained; and I think I can show that great accuracy is not incompatible with a very high initial velocity—say of fully 2000ft.—derived from using a small bore with a slow spirality of rifling, or large charge of powder and a light bullet. In proof of this I inclose diagrams made with a ·450 gauge single rifle, taking 136gr. (5dr.) C. and H. No. 6 powder and a hollow-pointed bullet weighing 270gr., using the standing sight only, and taking the sight as nearly as possible in the same way (*not* fine and full) up to 150 yards. By taking the foresight full, the standing sight is good for all practical sporting purposes to over 200 yards. At 100 yards you will observe that the rifle shoots into 3in. That this is not an exceptional rifle, but what I am in the habit of turning out, both single and double barrelled, I would refer you to such well-known sportsmen as Capt. Horatio Ross, Mr. Edward Ross, and "Rohilla," and if necessary to many others. I inclose a letter from Capt. Ross, written so far back as June, 1876, giving the results of some experiments made by him, with the assistance of the well-known rifle shot Mr. Wm. Ferguson, of Inverness, with a ·450 gauge 5dr. rifle, which letter you are at liberty to publish.

"DEAR MR. HENRY,—I yesterday gave the 'Queen of the Forest' a severer trial than I ever did previously.

"I was anxious to take advantage of the rifle range and target here, to ascertain exactly what its trajectory really is. I got Mr. Ferguson to assist me, as I consider him to be one of the most careful painstaking rifle shots we have.

"We began at 100yds., and fired shots at 130, 150, 180, 200, 220, 230, 250, 275, 300, 325, 350, and 400 yards.

"We aimed at the same spot as at 100yds. up to 250yds., using the first sight. We found that up to 230yds. there was no perceptible drop.

"At 250yds. we had to put up the flap sight, which gave very satisfactory results as far as 350yds., after that, at 400yds., we found the drop considerable and sudden.

"Mr Ferguson said that, until he had shot this rifle, he had no conception that it was possible to make a rifle which, up to 230yds., had such a flat trajectory.

"Yours very truly,

(Signed) "HORATIO ROSS."

Some sportsmen prefer a heavier bullet, and with the above rifle and charge there is no difficulty in increasing the weight to, say, 350 or 360gr., and yet retaining a trajectory sufficiently low for all practical sporting purposes, using the standing sight only, to 150 yards. I consider the light bullet, however, best for use against soft skinned animals, from deer up to and including tiger, as, owing to its greater velocity the smashing power is enormous; but for tough skinned and large boned animals the heavier bullet is, owing to its greater penetration, to be preferred.

Inclosed is a note of the various gauges of, and charges used with "Express" rifles.

To show the striking power of the "Express" bullet I forward a steel bullseye, 1¼in. thick, from my target, with a hole about 3in. by 3½in. driven right through the solid steel; also part of a steel bullseye, 3in. in diameter and 2in. thick, knocked to pieces by the bullets.

In my previous notes I stated that my early experiments with a low trajectory rifle were made with one of ·451 gauge. This is, of course, as we measure now, but at that time only the gunmakers' gauge was used, according to which the bore would be about 50.

In connection with my former remarks on long range rifles, I may mention that in the year referred to (1852) I tried some experiments at Dalmeny Park at 1000 yards, and at a target placed on Cramond Island in the Firth of Forth at 1600 yards, shooting from the shore. I will not say that the shooting was good, as the gauge of rifle, viz. 25 or ·577, was too large, and the spirality of rifling—as we have since ascertained—was too slow to give accuracy at these long ranges, but a note of such a thing having been done may be interesting as recording one of the earliest attempts at long range shooting since so wonderfully developed.

To show the great accuracy that can be obtained with the long range rifles of the present day under favourable circumstances, I inclose two official diagrams made at Enfield with a Martini-Henry rifle and Henry ammunition at 500 yards, giving the surprisingly low mean radials of under 2in. and 3in. respectively. These are supposed to be the finest diagrams ever made.

### By Mr. F. OSBORNE.

Weight of Rifle.—I find that I am alone in noticing this important point. Where would shot-gun definitions and comparisons be if this matter was not attended to?

Initial Velocity.—In this matter I find myself considerably more exacting than anyone else, but point to the following remarks in support of my views. Mr. Metford in his second paragraph says, "speed is valuable," "as the smashing power increases in the square ratio of speed, not merely with the speed." Sir H. Halford gives a table of *four* kinds of Express rifles (in which the latter kind would certainly be struck out as an Express), *two* of the remaining three have velocities of 2000ft. and 1830ft. each. Mr. Henry also gives an express with 2000ft.

Range Trajectory or Bullet Drop.—In opposition to Mr. Rigby, I fail to see why the 200 yards should enter into the question at all, as I do not think it possible within ordinary proportions, to construct a rifle giving a decent up and down group from 25 yards to 200 yards *with the same sight.* Mr. Metford says, in his fourth paragraph, "most shots are under 100 yards," &c. Mr. Henry also appears to indicate 150 yards as the Express limit. Sir H. Halford also prefers to give 100 yards as the range for diagrams, though he makes two statements about bullet drop that I fail to reconcile. First, "the fastest Express (drop) is 16 INCHES" (between 100 and 200 yards). Again, "gunmakers sight their rifles 6in. or more high at 100 yards. This at 200 yards will make a rifle shoot only 4in. low." [NOTE.—This gives a total drop of 10 INCHES between 100 and 200, as against 16in. as stated in the previous paragraph. He has in a previous sentence expressed himself in favour of rifles being sighted 3 INCHES HIGH at 100 yards. Either, or any, way he is, I take it, against the 200 yards range being included.]

With regard to Mr Metford's table of trajectories, &c., I note that he gives for bullet drop with 1900ft. initial speed 5in. nearly at 100 yards, the air resistance *not* being taken into account. Has the effect on the bullet drop of recoil, or "jump" of rifle acting the other way, been taken into account? A very illustrative experiment bearing on this point is given in Sir J. Whitworth's book "Guns and Steel" (Longmans, 1873), pp. 60, 61.

BULLET DROP.—I find the value I give for bullet drop between 50 and 150 yards much within the values indicated by Messrs. Rigby, Metford, and Sir H. Halford; but, as I have obtained my data from actual practice in firing rifles with sporting sights, I cannot materially alter my figures, though a certain amount of error may have crept in, owing to the practical difficulty of aiming exactly alike at all three ranges at the same bulls-eye, with ordinary sporting sights.

ACCURACY.—We seem to be on all fours on this point, or nearly so. Mr Metford's standard for single Express at 100 yards "should be covered by the *fist*," is sufficiently easy, though why *ten* shots? Such a number would be likely to lead to error unless some amount of time lapse between shots to prevent overheating. I suppose Sir H. Halford's diagrams are those of single rifles only, especially with the lighter charges.

RECOIL.—No one notices this feature, practically a most important one, as, if a rifle cannot be used with something like comfort, its other good points are rarely brought out. I fail to see, therefore, how Sir H. Halford can lay down weights of charges without weights of rifles to correspond. I have always considered the two as having an extremely intimate connection.

SOLID BULLETS.—An account of a successful use of solid bullets with Express rifles appeared in the *Field* in November, 1879, therefore I am in no way responsible for their introduction, though I can understand their possible value against very refractory-hided animals, &c.; but this matter can wait.

To conclude: In deference to the general leaning towards admitting rifles as "Express," with moderate or comparatively low velocities, I think we might put the minimum at 1800 or 1750ft. instead of 1900ft.—*not less*, as I think it will be well to exclude from the strictly "Express" class proper, either "Miniature Express" on the one hand, or "Miniature Cannon" on the other. As to the *bullet drop* between 50 and 150 yards being *4in. or thereabout*, I mean by this—from the centre of group made at 50 yards, to centre of group made at 150 yards, rifle fired from shoulder rest, aiming as near as may be at same spot, the sight being adjusted to suit the 100 yards range. An inch, or even two, may be added to this, but I see no reason why any greater addition should be made.

Yours faithfully,

FRANK OSBORNE.

## EDITORIAL COMMENTS ON THE CORRESPONDENCE.

It will be observed that there is a considerable disagreement among the above high authorities as to the exact limits of the requirements necessary to constitute "an Express." Sir H. Halford, Mr. Metford, and Mr. Henry consider 1600ft. muzzle velocity sufficient for the purpose, while Mr. H. Holland and Mr. Osborne contend for 1750 or 1800ft. in an ordinary Express. This high velocity is required for two purposes—first, to insure sufficient expansion of the bullet in the flesh of the animal shot at, and consequent smashing power; and, secondly, to obtain so low a trajectory as to make one sight answer, "fine or full," at any distance up to 150 yards. Now the amount of smashing power required it is not easy to settle, but the trajectory and accuracy form matter for experiment, and to obtain a public demonstration of what can be done, I instituted a public trial last autumn, which may be considered to have settled the question beyond dispute. It was then shown that even with a muzzle velocity of 1750ft., the above requirement was only just obtained, so that I think it may be fairly laid down that an Express rifle ought to possess that speed, especially as it was found to be consistent with as great accuracy as can be desired. Finally, therefore, I propose to define the Express as a rifle with a trajectory not exceeding four and a half inches at 150 yards, for which a muzzle velocity of at least 1750ft. per second is required. This velocity is obtainable with charges of powder varying from 1 to 2 of lead to 1 to 3½, according to the bore, and with such accuracy as to insure hitting a vital part—*ex. gr.* the heart or head—at 150 yards. For further particulars on this point, I must refer my readers to the report on the Rifle Trial of 1883, hereafter given.

## WHAT IS A SPORTING RANGE?

In different countries, with various kinds of game, the conditions under which the latter are pursued for purposes of sport will be such as to preclude any hard and fast rule on the subject. In this country, at all events, 150 yards may be regarded as the maximum distance at which game is shot at, and, no doubt, the average is considerably within a hundred yards. In India, according to both Capt. Forsyth and Sir S. Baker, the same rule applies. The former, in reference to jungle shooting, writes: "One half at least are shot at under fifty yards, three-fourths under seventy-five yards, and all, without an exception, under one hundred yards; that is to say, these are the distances at which animals are usually killed in jungle shooting." This is the general opinion of sportsmen; but for work on hills and other open situations, when "bright moments" occur, a shot at 150 yards may sometimes be made. Beyond this distance, the difficulties connected with judging distance correctly, the effect of wind, and the consequent liability to hit without killing the game, and thus send it off to a lingering death, will generally make the good sportsman pause, and will lead to an endeavour to get nearer, even at the risk of losing his shot.

Mr. Van Dyke, who is the best and most reliable modern

American authority, sums up a very well argued chapter on this subject in the following words: "For the last three years, my rule has been to shoot at nothing beyond 150 yards, if there is an even chance of getting closer to it, and not to shoot even that far if there is a fair prospect of shortening the distance. I fully believe I have gotten more deer by it. I certainly know that there have been fewer broken-legged cripples. For deer and antelope on the plains, fifty yards might be added to this distance; for elk, another fifty yards; and for buffalo, another fifty. Beyond this point, you had better make it a rule to get closer"* (pp. 317-318).

But in Southern Africa, where game has been, and still is, more plentiful, though wilder, than in India or Great Britain, a much longer range is desired, and especially by the Boers, who are not contented with a rifle unless it will perform well up to 800 yards. This can only be used for pot-shots at herds of deer; but there is no doubt that at 400 and 500 yards, with their fine power of sight, they do often kill game at such distances. Consequently, before the definition of a sporting range can be given, the locality where the rifle is intended to be used must be ascertained. In deciding on the proper range of a rifle, it must not be forgotten that the longer ones can only be obtained at the sacrifice of trajectory, which is increased from 4½ inches at 150 yards in the Express, to about double that amount in the Martini-Henry and still more in the Enfield. The South African rifle is thus, of necessity, much less useful at short ranges than the Express; because, not only must the exact range be ascertained—which is a difficult matter—but the sight must afterwards be altered to suit it, with a sacrifice of time, or the game will not be bagged with anything like the certainty which the sportsman desires.

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* "The Still Hunter," by Theodore S. Van Dyke. New York: Fords, Howard, and Plunkett; London: Trübner and Co.

# CHAPTER III.

## RIFLING MACHINES.

### MESSRS. GREENWOOD AND BATLEY'S AND MESSRS. MUIR AND SONS' RIFLING MACHINES.

### Messrs. Greenwood and Batley's Rifling Machine.

In proceeding to describe the mechanical details connected with grooving rifle barrels, I must refer my readers to the frontispiece of this volume, which is a representation of a modern rifling machine by the celebrated firm of Greenwood and Batley, of Leeds. It is a substantial structure, some twelve feet in length, the left foot being some six inches lower than the right one, giving such an inclination to the entire machine as has been found necessary to insure the flow of lubrication down the barrel during the cutting process. As shown in the illustration, the machine is arranged for operating upon *single* rifle barrels only; *double* rifle barrels require some changes in detail in no way affecting the general principle of the machine. The inclined "guide bar" in front of the machine is used to give the amount of twist or degree of spiral desired in the groove to be cut. One end can be moved only upon the fixed centre shown on the right; the other end can be adjusted to any desired angle within the scope of the machine by means of the slotted arm to which it is fastened. The main slide or "saddle" receives its motion up and down the "bed" from the central main screw, this being driven from the pullies at the extreme right; their motion is transmitted through gearing not visible in the engraving. The vertically working toothed "rack" carried by the saddle is engaged at its lower end with the guide bar; consequently, as the saddle travels along the bed, an amount of motion is imparted to the rack varying in proportion to the inclination given to the guide bar. As shown in the illustration, a considerable amount of this motion is imparted to the rack; consequently a quick twist would be thus cut in the barrel operated upon. If the lower end of the guide bar was raised in the slotted arm until more nearly parallel to the path of the saddle, of course the motion of the rack would be much less, resulting in a slower twist being imparted to the grooves. The motion of the rack thus obtained is converted into a circular one of the "spindle" (situate across the upper part of the saddle) by means of the small spur wheel or pinion upon it gearing into the rack. This spindle carries the "cutter rod" with tool holder attached, to which latter, by the means I have endeavoured to explain, is imparted the compound motion required in grooving the barrel. The barrel is held in a "chuck" or holder, in this case possessing the power of self-centering its work, and carrying a division plate with the same number of equi-distant notches as grooves are intended to be cut; thus enabling the chuck to be moved round and secured while each succeeding groove is operated upon. Above the chuck is placed the vessel holding soapsuds or other substance used to cool and lubricate the cutting tool when at work. The breech end of the barrel being secured in this holder, the muzzle end is steadied in an arrangement shown in the engraving—care being taken that the barrel so held is duly coincident with the spindle carrying the tool holder; this latter is then passed down and through the barrel—the cutting edge of the tool being prevented from coming into contact with the bore by the means described in treating the full-sized sketch of the "cutter box." To the "feed screw" of the cutter box is then attached the small "back rod" seen at the extreme left of the machine—the use of such rod being to control and regulate the amount of "cut" put upon the tool by the operator. The wheel gear and indicating dial through which it passes are the means of effecting this end—in some cases automatically by the machine, but in this case, and generally, by the man in charge, who functions this apparatus by means of the hand-wheel just in front of and below the grip wheel of the barrel holder. The back rod has a spiral groove cut along it of the same "pitch" or degree of twist that the barrel groove is intended to have; it slides freely through the hollow shaft at the extreme left of the machine. A stud or key inside this shaft engages in the groove in the rod, so that when the shaft is rotated the rod also turns, though the longitudinal motion of the rod through the shaft is not interfered with; thus, as the cutter passes up and down the barrel the back rod follows it in exactly the same spiral path. It must be noted that the cutting work is done by the upward (from left to right) travel of the saddle; therefore, when this latter is down or near the breech end of the barrel, the cutter has passed beyond and out of the muzzle, and is ready to be so adjusted as to cut a shaving from the bore. By turning the hand-wheel connected with the back-rod mechanism, the operator withdraws the feed screw in the cutter box a determinate amount (registered by the finger on the back-rod shaft upon the fixed dial plate), thus allowing the cutting tool to rise in its bed and protrude into the bore of the barrel; the machine is then put in motion, the tool being drawn through the barrel and delivering its shaving upon passing out of the breech end, the machine stopping at the same time. This process is repeated until the groove is the correct depth, when the barrel chuck is moved to its next division, and so on until the barrel is finished.

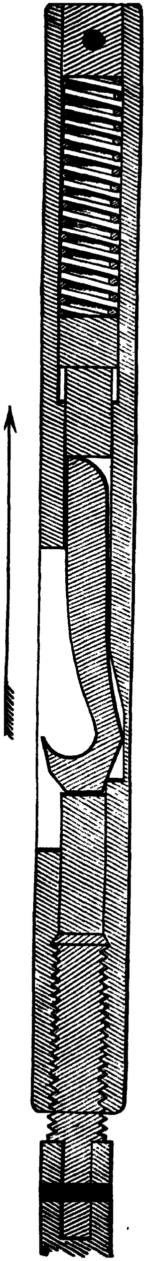

FIG. 5.

I have, so far, only described that plan of grooving rifle barrels, in which a uniform twist is produced. When a varying spiral is required, the guide bar has to curve so as to approximate to the desired variation in twist of groove, and the arrangement for cutter, feed, &c., modified accordingly. When a varying depth of groove is to be produced, the desired end is obtained by modifying the pitch of spiral groove cut in back-rod, so that it shall disagree to a certain extent with pitch of twist in barrel; thus, during the passage of cutter through the barrel, the back rod is operating on the feed screw with the result of increasing or decreasing the amount of cut applied. The accompanying sketch shows in section a cutter box or tool holder, used with this machine, attached to the cutter rod at one end, and with the back rod in connection with the feed screw at the other end. The cutting tool fits in a slot cut in a cylindrical box (this fitting the bore of barrel to be rifled), and rests with an inclined face or bearing, upon a step, also abutting against the feed screw, and kept firmly in its place by the strong spiral spring shown in the forward end of the box. When the feed screw is withdrawn, the pressure of the spring causes the tool to follow, consequently raising it by the action of the inclined face upon the step in the box; when the feed screw is reversed, of course the cutter moves forward and sinks in its recess.

I must here mention that this admirable system of cutting the grooves in rifle

contact with stops fixed to a rod of suitable length for a minimum or maximum traverse. This rod is coupled up to a series of levers to the strap fork—the motion of the carriage causing the strap to be moved from one pulley to another for the reverse motions as on a planing machine. To give the twist or spiral, the rifling bar is coupled up to a spindle fitted on a carriage, which is free to revolve or remain stationary at the operator's will; on this spindle a wheel is keyed, gearing into a split carrier wheel; this in turn gearing into a rack sliding on the carriage at right angles to the spindle. Motion is given to the rack by being coupled to a "former bar," of length sufficient for full traverse of carriage. This bar is secured by bolts to brackets projecting upon the body of machine. Grooves for the bolts run the length of the brackets, so that the former bar can be fixed parallel or at an angle to centre of machine. If the bar is placed parallel, motion is not given to the rack; but directly the bar is placed at an angle with the centre, motion is given to the rifling bar from the wheels and rack by causing the carriage to traverse.

To give equal divisions and the number required, the dividing head before mentioned consists of a hollow mandril, in which the barrel to be operated upon is fixed. On this mandril a dividing plate is fixed, with a suitable catch, &c., for holding the mandril stationary—the operation of dividing being done by the attendant; that is, when one groove is finished, he causes the mandril to revolve to the next division.

The rifling bar is bored up at one end to receive a suitable cutter, which is so arranged that, at the end of each cut, the tool can be drawn below the diameter of barrel, so as to avoid dragging or breaking the cutting edge. This can be done without stopping the machine, and is worked by suitable gearing from the centre of machine—that is, by hand wheel and mitres on the shaft running to extreme end of bed. At this end, a spur wheel gears into one keyed on to a hollow spindle on a bracket secured to bed—the spindle in this bracket being perfectly true, and in a line with the dividing head and spindle on carriage. The spindle is bored through, and receives a steel die with a square hole through, so as to allow a square bar to move freely. On the spindle nose a pointer is fixed, to indicate parts of revolution on a fixed index. The end of the bar is coupled up to a screw fitted in the rifling bar, this screw moving the tool in or out by the aid of an inclined plane on the back of the tool.

To put on a cut or withdraw the tool, and give an increasing depth, the operation is as follows: To put on a cut, the hand wheel at centre of machine is caused to revolve, the given amount is indicated by the pointer on the spindle of the feed bar bracket and the index plate. The spindle thus causes the square bar to revolve with the screw in the rifling bar. This screw in turn causes the cutter to slide up or down a projecting inside rifling bar—thus advancing or withdrawing the tool at pleasure.

For giving increasing depth to the groove, the hand wheel is held to the required number on the index plate—the square feed bar thus not having any circular motion. The screw is acted upon by the circular motion to the rifling bar; thus an increasing or decreasing depth of groove can be given according to pitch of feed screw and angle of former bar.

# BOOK IV.

## THEORY OF PROJECTILES, BY "T."

## CHAPTER I.

### INTRODUCTORY.

THE following remarks are written with the hope that they may serve to convey to non-scientific sportsmen and rifle-shots some little idea of the theoretical principles connected with the employment of fire-arms. As with many other discoveries of great importance, the invention of gunpowder was carried into practical use long before the principles underlying its employment received any great amount of scientific investigation. Even in the present day, most people who are accustomed to handle fire-arms have learnt to do so without having troubled their heads about the theory of the motion of projectiles. But practical men need not for that reason look upon theoretical studies as altogether needless. By dint of long practice and keen observation they may have become excellent shots; but, for all that, they might possibly have acquired their skill with fewer disappointments, and less expenditure of time and trouble, had they been spared the pains of finding out for themselves the origin of many little difficulties, which at first they may have looked upon as unaccountable, but which a fuller acquaintance with scientific principles might have led them to regard merely as natural consequences of pre-existing causes. And although, eventually, they may have become perfect masters in the manipulation of their favourite weapon, and able to do the right thing at the right moment, it not unfrequently happens that they do it by a sort of natural impulse rather than as the result of deliberation, and are quite incapable of giving to others a sound reason for the faith that is in them. Having, however, worked out their results in a practical way, it is not unnatural that such persons should consider it a waste of time to study the origin of facts with which they have long been familiarly acquainted.

The adepts who, by reason of their innate abilities and long experience, have got beyond the bounds of learning, are exceptional personages, for whom the following pages have not been written. Nor, on the other hand, is it imagined that the information can add to the knowledge of those rifle-shots who have already studied the subject scientifically; while such readers will readily perceive how much more concisely they could themselves set forth the same facts, and how much more clear they could render them by the use of algebraic symbols.

There are, however, many other men, not wanting in skill, who readily admit that plenty of "wrinkles" yet remain to be picked up, and who are perfectly willing to accept information, but have a mortal aversion to all mathematical formulas. To such persons more especially it is hoped that these observations may be of service; and it is for them, indeed, that these notes are mainly intended. And if they may not derive much actual advantage by the perusal, they may possibly find some recompense for their pains in the awakening of reminiscences of bygone days, when game got off scatheless, owing, as was then imagined, to unaccountably bad shooting, though, after all, it may have been mainly due to the operation of some natural law that hitherto had not come into operation in the same way within that sportsman's particular experience.

Two gentlemen, for instance, went on a shooting excursion across the Himalayas into Thibet; and in detailing their adventures in the *Field*, one of them said, with respect to the hunting of the "gooral," or Himalayan chamois, "Our first experience of this sport was most unsatisfactory, and it was a considerable time before either of us brought one to bag. At first we used to miss the most easy shots, apparently, and could not account for it in any way, for we were both tolerable shots in the plains." The conclusion they came to was, that it was owing to the nature of the ground, and the difficulty of judging distances. Possibly something was due to this; but it does not appear to have occurred to them that there was another very probable cause of error, viz., their height above sea-level; for the great difference in barometrical pressure at high elevations would alter considerably the trajectory of the bullet as compared with what it had been on the plains, for which the weapon had been sighted; and they might consequently clean miss an animal that they would have hit with certainty at the same distance, under conditions to which they were accustomed.

Here, then, is one incident which may not occur to every rifle-shot, but which, nevertheless, may be worth bearing in mind. Many other matters are equally or more deserving of consideration; so numerous are they, indeed, that it is not to be expected that they will be exhausted in these pages. Let us, however, attempt to deal with some of their most salient points.

# CHAPTER II.

## CAUSES THAT INFLUENCE THE FLIGHT OF BULLETS.

DIRECTLY or indirectly, a bullet is subjected to many influences, both before and after it leaves the barrel of the rifle; and each separate influence has greater or less effect according to variation in circumstances.

We have (1), as the originating cause of the bullet's motion, the gases produced by combustion of the powder; and the extent of the action of these gases will be varied, not only by the quantity of powder burnt, but by the physical condition of the compound, such as the size of the grains and the density due to the amount of pressure the "cake" has undergone in the process of manufacture, besides any difference which may occur in the proportion of the ingredients. Even when successive charges of the same powder are used, you cannot rely on getting absolutely exact results; for, although the sulphur, saltpetre, and charcoal may have been very carefully weighed, and great pains have been taken in the mixing process, the powder is, after all, only a mechanical mixture, and the proportions may vary somewhat in different parts of the same batch. Thus, our Government powder is said to be composed of 75 per cent. of saltpetre, 10 of sulphur, and 15 of charcoal; but in samples taken from the top and bottom of a barrel by Mr. (now Sir F. A.) Abel, one sample proved, on analysis, to have almost exactly 75 per cent. of saltpetre and the other only 74½ per cent.; one contained 10 and the other 10¼ per cent. of sulphur; and one had ¾ per cent. more charcoal than the other. It is not to be expected, then, that they could produce absolutely equal effects. Moreover, the evenness or otherwise of the grain of the powder may also influence the results obtained from successive cartridges; and so may any differences in the manipulation of the powder. The force, too, that will be exercised by a charge of gunpowder is not dependent merely on its weight and make; it is by no means, in fact, a fixed quantity, but varies with the degree of resistance encountered by the expanding gases. The potential force of the charges used in small arms is vastly in excess of the power actually developed under ordinary circumstances; and an increase in the resistance—whether it arise from additional weight of projectile, more rigid turning down of a cartridge case, or obstruction of any other nature—may produce a considerably increased development of the dormant powers of the explosive.

(2) Besides the direct effects produced by the force of the powder, the speed of the bullet is influenced by the friction that arises as the projectile is forced through the barrel, and likewise by the resistance of the partially-imprisoned air; for air there must be in the barrel when the charge is fired, and it cannot possibly get out of the way of the bullet. The walls of the tube prevent any such thrusting aside as would occur in the open atmosphere, and the speed of the projectile is too great to permit of air moving away in advance without undergoing condensation; so that there must be increasing compression, and corresponding resistance, as the bullet drives the air from breech to muzzle. The resistance which is due to friction would vary too, according to the nature of the rifling and rapidity of twist, as well as with the form of the bullet; for deep grooves and rapid spiral must offer more obstruction than shallow grooves and slow twist; while a spherical ball, which only touches in a narrow line at its

circumference, would move much more freely than elongated bullets, the resistance from which increases with their length, and the extent of their hold upon the grooves. Beyond these effects, there is the further obstruction which arises from fouling, and which varies with the powder, the nature of the rifling, and the moisture or dryness of the atmosphere. After black powder is burnt, nearly two-thirds of its weight remains as solid residue, and, although the larger portion of this is necessarily blown out of the barrel after the projectile, a considerable quantity is deposited within, especially when there are inequalities in the bore, such as deep rifle-grooves, wherein the dirt can readily lodge.

(3) Another of the influences affecting the course of the bullet is the recoil-movement, or "jump," which occurs in the gun before the shot has left the barrel. Some persons contend that no recoil takes place until after the shot has left the muzzle. Practical experience, however, goes to prove that the course of the bullet is affected by the motion of the barrel—which would be strange indeed if there were no movement until after barrel and ball had parted company; while theoretical considerations go to show that the recoil-movement must receive its initiation as soon as the bullet is set in motion, although the recoil would not be complete till after the projectile quits the muzzle.

(4) The resistance of the atmosphere, after the shot has departed from the barrel, is one of the most potent of the influences that affect the course of the projectile. Except for the resistance of the air, bullets would go on with undiminished speed, regardless of distance; and differences of size, shape, or weight of projectile would matter nothing as regards trajectory, for all that start with the same speed would follow the same curve. Under existing circumstances, however, different trajectories are caused, not only by different velocities, but by variation in shape of bullets of equal weight,

difference in size of bullets that are similar in form, and variation in weight of bullets that are alike in size—whether such variation be due to difference in density of the metal, or to some bullets being solid and others hollow. The trajectories of bullets will also be affected by variations in the density of the atmosphere, whether arising from differences of temperature and moisture, or differences of atmospheric pressure as shown by the rise and fall of the barometer in the same locality, as well as by the rarefaction of the air *in high mountain regions. The longer the range of the projectile, the greater, of course, will be the effect on its flight;* but spherical and hollow bullets are more sensitive to the change than heavy elongated projectiles of solid metal; and the effect would consequently be noticeable with the former at shorter distances than with the latter.

(5) The force of gravity, though here put last on the list, has far greater influence than any other in determining the bullet's course. Except for the effect of this force, all projectiles would fly in a straight line; they might be a greater or less time in reaching their object, according as they have low or high speed, but their course would be as direct in the one case as in the other. Under the influence of gravitation, however, the course never is direct, but invariably is curved, though not in the same degree; and the slower the speed, and longer the distance, the more marked is the curve.

Such being the principal influences that affect the course of bullets, it may be as well to examine a little more closely some of their effects. But, instead of taking them exactly in the order just given, it may be desirable, perhaps, to commence with the one last touched on, as some of the remarks made with respect to the action of the force of gravity may facilitate explanation when other points are touched on, and thus we may "kill two birds with one stone," or get two illustrations from one bullet.

# CHAPTER III.

## THE DROP OF THE BULLET.

In *taking into consideration the progress of projectiles through the air, a little fact* which is *frequently* overlooked should ever be borne in mind, viz., that from the instant the shot leaves the muzzle of the gun, it begins to drop down below the line in which it was fired; consequently, every yard, every inch, of the trajectory is curved, although to a very trifling extent at first. The "perfectly flat trajectory," too often spoken of, has no real existence: it could only be produced by the invention of a bullet able to set at defiance the laws of nature.

Some time ago, a sportsman writing to the *Field,* and recording the performance of a rifle in his possession, stated that it had a perfectly flat trajectory up to 150 yards. It probably never occurred to him to ask himself, "Why should a bullet go 150 yards in a perfectly straight line and then fall away from it?" He doubtless did not take into consideration any other fact than that he looked in a straight line along the barrel, and did not put up any sight for a range of 150 yards, whereas for longer distances he did put up a sight. The fact that the inside and the outside of the barrel were not parallel may have escaped his observation, or, if noticed, may not have caused him to reflect that, although his line of sight outside the barrel might be horizontal, and go straight to the object on which his eye was fixed, the bore, when he took aim, had an upward slope from breech to muzzle, and that therefore the bullet was not directed at the object aimed at, but at a point some distance above that object. Still less would it be likely to occur to him that, supposing there to be a difference of, say, $\frac{1}{10}$th of an inch in thickness of barrel or height of rib or plate at the two ends of a 27-inch rifle, this difference would be repeated 200 times in a range of 150 yards, and thus amount to 20 inches in such distance; while even more remote would be the inference that about midway in the range (or from 75 to 80 yards) the bullet would be fully 5 inches above the line of sight.

But, although it may be excusable in a sportsman to overlook such facts, and make statements similar to those above alluded to, the same excuse will scarcely avail a gunmaker if he utters assertions of a like nature; for he can hardly be unacquainted with the reason for constructing rifles with so much taper of barrel or thickness of plate as to dispense with movable sights up to 150 or 200 yards, nor can he be unaware of the effect that must be produced upon the elevation of the bullet at lesser distances. Yet it would not be difficult to find gunmakers' advertisements claiming for Express rifles a flat trajectory up to 200 yards, regardless of the fact that bullets which strike the mark would, according to their velocity, have been some 7, 8, or 10 inches above the line of sight in traversing that distance.

Such gunmakers were the subject of some animadversions by a correspondent of the *Field,* of a more observant turn of mind than the one just alluded to. He complained of the ill effects resulting from the construction of rifles in which the back sight had been made of undue height in order to produce a fictitious appearance of low trajectory at long ranges. In a rifle which he had bought, an otherwise good weapon had thus been rendered comparatively useless until he knocked out the back sight, which was contrived to show such a "flat trajectory" at long ranges that the bullet struck high above the mark at short distances.

As already intimated, an *absolutely* or *perfectly* flat trajectory (for both these adverbs have occasionally been made use of) can have no existence whatever. The most limited range must take some small space of time for the bullet to traverse; during that time the bullet drops, and the trajectory becomes curved. There is, no doubt, a vast deal of difference in the curves described by projectiles fired from different rifles, and by different bullets fired from the same rifle—the line of flight being, in some cases, very much less arched than in others. Consequently, one trajectory may be *relatively* flat, as compared with another; but beyond relative flatness we cannot go; and in considering why it is that one trajectory is flatter than another, we shall likewise see that, although the curve may be lessened, it never can be changed into a straight line.

The ordinary experiences of daily life make us all acquainted with the fact that, if we pick up any object of sufficient density—such, for example, as a bullet—and then, by unclosing the finger, leave it without support, it immediately begins to drop towards the earth. It does not remain in suspense an instant after its release, but, commencing with a slow downward movement, gains speed rapidly as it falls to the ground, and attains greater and greater velocity the further it descends. In like manner, everyone would consider it a matter of course for a weight falling from the height of the roof to give a more severe blow than if it had merely rolled off a chair or a table. But comparatively few persons take the trouble to ascertain the reason of such universally admitted facts. Most people are content to know what they cannot help. knowing, without thinking of cause and effect; and when they find themselves face to face with certain facts that do not ordinarily come within the range of their experience, they are apt to overlook the real origin of unexpected results, and to attribute them to other causes, sometimes very wide of the mark.

Thus, a man who is a fair shot with a rifle that he has been accustomed to use at short distances, might become possessed of an "Express" such as has been recently alluded to, and have been told by the maker that it has a "point-blank range up to 200 yards;" for "point-blank" is another misleading expression in current use. From experience with his old rifle, up to 70 or 80 yards, he considers he knows well enough what "point-blank" means; and he is very well satisfied with the results when he tries his purchase at 200 yards. He finds, however, when he comes to use his new rifle at shorter ranges, that things do not go on so satisfactorily as he had anticipated; he fires "point blank," as he has hitherto done, at accustomed distances, and the bullet is planted some inches higher than he expected. It is not surprising that he should be put out thereby; and very possibly it may never occur to him that, whatever the distance for which a rifle is sighted, the bullet must be above the line of aim at intermediate distances, whether twenty-five, fifty, or a hundred yards. Why it must be so, however, becomes clear enough when one reflects upon the circumstances.

On making its exit from the barrel, the bullet drops as inevitably as it would do on being let loose by the fingers. So long as it remains within the bore, the ball is held up; but no sooner does it pass out from the muzzle, and consequently lose support, than the force of gravity takes effect on the bullet, and draws it downward. If the barrel be held horizontally, the shot begins at once to fall below the level of the position from which it started; but if—as usually is the case—the barrel has an upward inclination at the moment of firing, the bullet necessarily rises from the muzzle, and yet (anomalous as it may sound) the drop goes on during the rise of the projectile, to just the same extent as if the barrel were horizontal. In the one case, the bullet will, in a quarter of a second, have descended 1ft. below the horizontal line; and in the other it will, in the same time, have descended 1ft. below the "line of fire," whatever may be the angle of elevation above the horizon. A very good example of this double motion is seen when a jet of water issues from the muzzle of a garden-hose or fire-engine. The liquid, as it shoots forth, ascends more or less above the mouth of the tube, according to the angle to which the muzzle is raised; and the stream meanwhile falls from the line of projection to just the same extent as if the pipe were horizontal. The "trajectory" of the water, moreover, depends upon the velocity of the discharge, and, as in the case of the bullet, the higher the speed the flatter is the curve; but, however great the velocity, the jet can never strike an object unless the tube is directed in a line above it, and the stream between any two points is consequently always arched. In short, the jet of water presents visibly to the eye a curve similar in character, but shorter and higher, than that which the bullet describes when projected from the gun.

The rapidity of the natural drop in projectiles is neither increased nor diminished by their weight, nor by the speed with which they leave the gun: the velocity of descent is dependent on the duration of the fall, or, in other words, on the length of time the bullet is in motion—as this it is that regulates the distance and velocity of the drop.

Supposing, for instance, that a number of guns, all differing in dimensions, charge of powder, and weight of shot—varying, in fact, from the largest cannon down to the smallest rook-rifle or saloon pistol—were levelled horizontally on the top of a cliff, say, 100 feet above the sea; and that, on being fired, the whole of the different projectiles started off evenly together from the edge of the cliff; the various kinds of shot, whatever their weight or velocity, would drop into the water at the same moment—the time of fall (at 16 feet per second, without air-resistance) being 2½ seconds for the 100 feet.

And if, simultaneously with the shots being fired, other bullets were dropped in a straight line down the face of the cliff, or let run down inclined planes (without friction), they would reach the same level in the same time, although some of the shot may have been propelled a quarter or half a mile, and described curves of various dimensions, while others may have run down slopes of different angles, and others not have varied at all from the perpendicular. If, however, there were the slightest departure from the horizontal position of the bore, the speed of the projectile would tell; for the greater the velocity and weight, the higher would the projectile go, as compared with a slower and lighter bullet, before decending towards the earth—that is, supposing the muzzle pointed upwards; whereas, on the other hand, the more quickly would the shot make its descent if the muzzle had a downward tendency.

The "drop" may be said, in short, to be a definite quantity, determined by time, and entirely independent of any onward motion of the projectile. It operates to an equal extent whether the barrel points upwards or downwards or is held perfectly level, and whether the projectile is large or small.

It has been ascertained by experiment that bodies falling from a state of rest drop a fraction more than 16ft. in one second; but for our general explanatory purpose the fraction may be disregarded.* If the body starts with an upward or

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* The fall varies slightly in different parts of the globe, increasing towards the poles and diminishing towards the equator—the attraction to the centre being greatest where the diameter of the earth is least, and *vice versâ*. The following will show a few differences in the amount of drop in one second:

| | ft. | in. | | ft. | in. |
|---|---|---|---|---|---|
| Greenwich | 16 | 1·15 | Trinidad, West Indies | 16 | 0·55 |
| Paris | 16 | 1·09 | Hammerfest, Norway | 16 | 1·42 |
| New York | 16 | 0·96 | Spitzbergen | 16 | 1·52 |

Thus between London and New York the difference of fall in one second is downward impulse, the 16ft. will be added to or diminished from the distance it would have reached in one second, had the body continued to move unobstructedly in the same direction for that period of time. Accordingly, if a shot were fired straight up into the air, it would, at the end of one second, be 16ft. short of the height it would otherwise have attained; and, if fired down a precipice, the bullet would be 16ft. below the point to which it would have been carried by its own velocity in the course of one second.

It will be obvious that, if a body starts from a state of rest, and goes on regularly increasing its speed, it must move faster at the end of any given period of time than it did at the beginning, and that the velocity must increase with length of time. We always see a railway train start slowly; and it goes on for a time gradually increasing its speed, although the actual force applied when travelling at 50 miles an hour may be no greater, or even less, than when the train moved slowly out of the station. A continued application of the same motive force produces continually accelerated motion, unless it is counteracted by some other force; and, in the absence of such counteraction, the exercise of a constant force for equal periods of time would impart an equal increment of speed in every such period.

Such is the case with falling bodies, as exemplified in the trajectories of bullets. Here we have in action a constant accelerating force known as the force of gravity, which imparts a downward motion at the rate of a fraction more than 32ft. per second for the time the bullet is in motion, whether it be seconds or only a portion of a second; so that 8ft. velocity would be imparted in a quarter of a second, 16ft. in half a second, 64ft. in a couple of seconds, and so on.

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about one-fifth of an inch, which may seem very trifling; but in a range of 1000 yards, with a Martini-Henry rifle, the total would amount to nearly two inches; and in similar ranges in Norway and the West Indies there might be a difference of drop of about eight inches—other things being equal.

A knowledge of the speed gradually attained in a given period of time would, however, afford to many people but little idea of the distance actually traversed in that time. Almost anyone, on being told that a certain train acquired a speed of three miles an hour in the first minute, and regularly increased its speed at the same rate, would at once perceive that in course of ten minutes it would have a velocity of 30 miles an hour, and that it would have double that speed in double the time. Nevertheless, it might puzzle him to say how far the train would have travelled in any given portion of the time; and he might even be incredulous if told that in five minutes, although the train would then have attained a velocity of 15 miles an hour, it would only have gone five furlongs, and that, at the end of the first minute, when moving at the rate of three miles an hour, it would not have proceeded 50 yards.

On the other hand, the fact of the train travelling nearly a mile in the course of the twentieth minute would be readily apprehended; and so would the statement that, by starting from 0 velocity and increasing regularly to 60 miles an hour, the average speed in the meantime must be 30 miles an hour.

It requires, however, but another step onwards to arrive at the fact that, with an average speed of 30 miles an hour, no more than 10 miles could be run in $\frac{1}{3}$rd of an hour, or 20 minutes; and the same method of estimation will quickly demonstrate that, as the average speed during the first minute (beginning from 0 and ending with 3) is but $1\frac{1}{2}$ miles an hour, the distance traversed in the $\frac{1}{60}$th part of an hour could only be the $\frac{1}{60}$th part of $1\frac{1}{2}$ miles (*i.e.*, 2640 yards), and therefore would not exceed 44 yards in one minute.

In the drop of bullets a similar process goes on. As already stated, the speed increases at the rate of 32ft. per second for the time occupied in the descent; hence it will be obvious that 8ft. velocity must be imparted in $\frac{1}{4}$th of a second.

It is not so apparent, however, that in this same quarter of a second the bullet would drop only 1 foot; yet, by having recourse to the method just adopted with respect to the train, it will be clear that such must be the case; for a bullet starting from 0 and increasing to 8ft. velocity would have a mean speed of 4ft., and progression at this rate for $\frac{1}{4}$th of a second could not carry the body more than 1ft. from its original position. But it is only when the periods of time are fractional that the progress seems so insignificant as compared with the speed; for the reverse is apparently the case when we get to whole seconds, as the distance then seems to increase with marvellous rapidity.

An accelerating velocity of 32ft. per second gives a drop of 16ft. in the first second, because it starts from 0 and ends at 32, and the drop is equal to the mean velocity. The next second begins with a velocity of 32 and ends with 64, so that the mean velocity is 48. The velocity and drop afterwards proceed as follows:

| Time. | Velocity at end of each second. | Drop in the respective seconds. | Total drop at end of each second. |
|---|---|---|---|
| 1 sec. | 32ft. per sec. | 16 feet. | 16 feet. |
| 2 ,, | 64 ,, | 48 ,, | 64 ,, |
| 3 ,, | 96 ,, | 80 ,, | 144 ,, |
| 4 ,, | 128 ,, | 112 ,, | 256 ,, |
| 5 ,, | 160 ,, | 144 ,, | 400 ,, |
| 6 ,, | 192 ,, | 176 ,, | 576 ,, |

The full second, with the rate of drop as here indicated, is, however, too large a unit of time for the sportsman's purpose, which requires, for the most part, fractions of a second to be taken into consideration, with drops of a few inches rather than hundreds of feet. Let us, then, take $\frac{1}{10}$th of a second as our unit of time, and we shall have very nearly 2 inches (*i.e.*, 1·93in.) as our unit of drop—which would be the extent of fall in a 50 yards range, with a bullet traversing the 150ft. at a mean velocity of 1500ft. per sec. On the same principle will the drop go on whatever unit may be chosen. Whether a full second, or a tenth or a hundredth part of a second, be adopted as the unit of time, the rate of progress will be as follows:

| Periods of time. | Units of drop in the respective periods. | Total units of drop at the end of each period. |
|---|---|---|
| 1st | 1 | 1 |
| 2nd | 3 | 4 |
| 3rd | 5 | 9 |
| 4th | 7 | 16 |
| 5th | 9 | 25 |
| 6th | 11 | 36 |
| 7th | 13 | 49 |
| 8th | 15 | 64 |
| 9th | 17 | 81 |
| 10th | 19 | 100 |

Taking, then, 2in. as the extent of fall in the first unit of time, the drop in the next equal period would be treble as much, or 6in. (making 8in. for the two periods); in the next equal space of time there would be five times 2in., or 10in. further fall (making 18in. in the three periods), and so on. The figures in the second column, multiplied by 2in., show the respective fall in each successive period, while those in the third column (also multiplied by 2in.) give the total of all previous periods. And, if it were possible for a bullet to pass through the air without losing speed, a shot that fell 2in. in 50 yards would fall 6in. between 50 and 100; 10in. between 100 and 150; and 14in. between 150 and 200—making 32in. altogether.

If, however, instead of a 2in. drop in the first period, any other space were taken—as, for instance, the $\frac{1}{50}$th part of an inch (or 0·02in.), which would be equivalent to the fall in $\frac{1}{100}$th part of a second—the same law would hold good. With a mean velocity of 1500ft. per sec., this drop would occur in a bullet by the time it had got 5 yards from the muzzle. In six such periods, or about 30 yards, the 0·02in. would be multiplied by 36, and amount to nearly ¾in.; and at the end of the eighth period, or 40 yards, the total fall would be

0·02 × 64, or about 1¼in. But, as before intimated, comparison of equal distances with equal times is not strictly correct, and is only assumed for facility of explanation.

The entire fall indicated in the last column of the foregoing tables will be observed to be the sum total of the drops separately indicated for the respective periods given in the previous column. Hence, 576ft. (at the end of six seconds), in the table on page 51, will be the total of the respective distances from 16ft. to 176ft.; while, in the next table, 100 (or any other number in the final column on the opposite page) will be the sum of the preceding figures in the middle column, up to the same period of time.

It is not necessary, however, to resort to this cumbrous mode of adding together the various figures in order to arrive at the required total, because the same end is obtained by the much more ready process of "squaring" the number of seconds, or other periods of time. Thus, 36 is the product of 6 by 6, as well as the sum of all the odd numbers from 1 to 11; for it will be observed that the middle column of the last table consists exclusively of odd numbers. So the figures in the third column in the first table are only the same odd numbers multiplied by 16ft. (which there is the unit of drop), and 576 in the final column is the product of 16ft. multiplied by 6 times 6.

The variation in the amount of drop in short periods of time may be better seen in the table on p. 54, where $\frac{1}{100}$th of a second and $\frac{1}{10}$th of a second are respectively taken as units of time, and are carried on for ten successive periods, so that the bottom of one column connects with the top of the next until full seconds are arrived at. In each case, the figures represent the total amount of fall at the end of the respective periods of time, but, where there are fractions, it has been thought unnecessary to work them out with great minuteness. The drop in the column for full seconds will be seen to be

100 times as great as in the previous column, and 10,000 times as great as in the column for hundredths of a second.

| Number of periods. | Hundredths of a second. | Tenths of a second. | Full seconds. |
|---|---|---|---|
| 1 | $\frac{1}{50}$ inch | 2 inches | 16 feet. |
| 2 | $\frac{1}{14}$ ,, | $7\frac{3}{4}$ ,, | 64 ,, |
| 3 | $\frac{1}{6}$ ,, | $17\frac{1}{4}$ ,, | 144 ,, |
| 4 | $\frac{1}{3}$ ,, | $2\frac{1}{2}$ feet | 256 ,, |
| 5 | $\frac{1}{2}$ ,, | 4 ,, | 400 ,, |
| 6 | $\frac{2}{3}$ ,, | $5\frac{3}{4}$ ,, | 576 ,, |
| 7 | 1 ,, | $7\frac{3}{4}$ ,, | 784 ,, |
| 8 | $1\frac{1}{4}$ ,, | $10\frac{1}{4}$ ,, | 1024 ,, |
| 9 | $1\frac{3}{5}$ ,, | 13 ,, | 1296 ,, |
| 10 | 2 ,, | 16 ,, | 1600 ,, |

With the mean velocity of 1500ft. per second, one of these columns would represent "drops" occurring at intervals of 5 yards, while the others would, in a similar way, apply to intervals of 50 and 500 yards; and the last figures in the respective columns would represent the total drop in ranges of 50 yards, 500 yards, and 5000 yards (or nearly 3 miles)—the last of which, of course, could only apply to artillery. Inasmuch, however, as projectiles inevitably lose speed during their flight, and consequently the same shot can never have the same mean velocity for different distances, the above figures cannot be taken as strictly applicable to any single shot, and could only be correct if applied to a series of separate shots giving an equal mean velocity for all the ranges indicated. If, for instance, a 12-bore spherical ball had a mean velocity of 1500ft. per second over a 50 yards range, it would leave the muzzle with a speed of about 1650ft. per second, which would be reduced below 1400ft. velocity in going the 50 yards. Obviously, then, the first half of the distance would be accomplished in less time than the second half; and the extent of the drop during the first half of any given range must consequently be less than one-fourth of the drop occurring in the full range. For short distances, however, the proportions may be assumed to be approximately correct; and it will suffice to say, in round numbers, that, with a mean velocity of 1500ft. per second, there would be a drop of about half an inch in the first 25 yards, and about an inch and a half between 25 and 50, making two inches for the 50 yards. And in like manner it may be assumed that the height of the trajectory is about one-fourth of the total drop, although it is always more than one-fourth. With heavy elongated projectiles the one-fourth approximates much more closely than with light Express bullets and spherical balls; and the longer the range the less accurate is the foregoing estimate, especially with the lighter bullets.

The writer of this was asked, not long since, to define the share in the formation of the trajectory-curve which is due to gravity alone, and the share which is due only to air-resistance. Strictly speaking, the whole is directly produced by the action of gravity, although a portion is the indirect result of atmospheric resistance. The drop of the bullet (from which the curve results) is, as recently stated, a definite quantity dependent upon the time of fall. The effect of air-resistance is to lessen the bullet's speed; it thereby lengthens the time taken to traverse a given range; and the drop is thus increased, by the force of gravity being enabled to operate for a longer period of time.

In one sense, however, an answer may be given to the foregoing question. If there were no air-resistance, the muzzle velocity of the bullet would be its velocity throughout the range; by dividing the length of range by the bullet's velocity, you get the time of the trajectory; and from this the drop may be ascertained. Thus, a bullet with 1500ft. uniform velocity would traverse 500 yards in one second; and there would be a drop of 16ft. due to gravitation alone. But, in actuality, the velocity is always decreasing, and a bullet that starts with 1500ft. velocity from the muzzle would have much less velocity at the end of 500 yards; consequently it would take more than a second to traverse the distance, and therefore would drop more than 16ft. The difference between 16ft. and the actual drop will be the portion due to the action of air-resistance.

It may be said, however, that this gives no idea of the extent of the drop indirectly caused by the air in any given distance; and such a remark would be perfectly true. It is easy enough to give the vague general answer, but by no means so easy to furnish the special reply directly applicable to any particular instance. Every case must be dealt with according to its own circumstances. You require, in the first place, to know the weight and shape of the bullet, the bore, and the velocity; from these facts, by a process of calculation that will hereafter be described, you may ascertain how much the velocity will be reduced in a given distance, and therefrom you may calculate the time the bullet would take to traverse the range, and from this period of time you will deduce the total amount of drop. When you have got such particulars, you may subtract from this total drop the corresponding amount derived from the supposititious case of the bullet losing no velocity, and the difference will be the portion due to air-resistance.

The knowledge of the result in one case will not, however, necessarily afford information as to the result in another, unless the velocities are alike, and weight and bore in the same proportions in both instances. An alteration in the initial velocity will give a different result with the same bullet; an alteration in the bullet will give a different result from the same initial velocity; and several different bullets, fired with the same charge of powder from the same rifle, will give widely divergent differences. Here are the estimated results (without descending to very minute fractions) obtained from firing a solid elongated bullet, a hollow elongated bullet, and a spherical ball, each with 6drs. of powder, from a rifle of ·577 bore. The two elongated bullets had very nearly the same muzzle velocity, but the spherical bullet had about 150ft. higher initial speed than the other two. The differences at 100 and 200 yards are given with all three.

| | Total Amount of Drop. | | Without Air-resistance. | | Difference. | |
|---|---|---|---|---|---|---|
| | In 100yds. | In 200yds. | In 100yds. | In 200yds. | In 100yds. | In 200yds. |
| Solid bullet | 6½in. | 32in. | 5¼in. | 21in. | 1¼in. | 11in. |
| Hollow bullet | 6¾in. | 34in. | 5¼in. | 21in. | 1½in. | 13in. |
| Spherical shot | 7½in. | 49in. | 4½in. | 18in. | 3 in. | 31in. |

From the middle column it will be seen that the action of gravity, *without* air-resistance, would give least drop with the highest initial velocity, and equal drop with equal velocity though different bullets. But the other columns show the greater effect of air-resistance on the lighter bullets, and the difference produced on the spherical ball is more than double the difference with either of the others. It is obvious, therefore, that no definite rule can be laid down which would apply to all cases. The subject of air-resistance will, however, be more fully treated of in the ensuing chapter.

# CHAPTER IV.

## ATMOSPHERIC RESISTANCE.

THE amount of resistance opposed by the air to the passage of projectiles is truly marvellous. As a rule, however, most people have very vague notions of the force of air-currents or air-resistance. Everyone, no doubt, has some personal experience of the power of the wind, as it drives him along or resists his progress in stormy weather; but ideas as to what the pressure amounts to are usually very indefinite. We hear, it is true, after the occurrence of disastrous gales, a good deal with respect to their estimated force; and the newspapers publish statements of the amount of wind-pressure which caused the destruction of the Tay Bridge or some other edifice. We learn that the wind exerts a pressure of about 20lb. per square foot when a gale blows at the rate of a mile in a minute; that a hurricane of 80 miles an hour gives a pressure of more than 30lb. per square foot; and that, if the velocity of the wind reaches 100 miles an hour, the pressure is raised to about 50lb. per square foot.

Such air-currents, however, except that they extend over vast surfaces, are insignificant as compared with the atmospheric pressures on projectiles moving at high velocities. The hurricane of 100 miles an hour travels less than 150 feet in a second, or with not one-tenth part of the speed of bullets from many sporting rifles.

Action and reaction being equal, the pressure produced is the same, whether air rushes at a given speed against a motionless body, or the body is propelled at the same rate in a calm atmosphere, or whether movement in both serves to produce a combined velocity of similar extent; so that there would be the same atmospheric pressure on the front of a locomotive when the train runs at 40 miles an hour and meets a breeze of 10 miles an hour, as when the engine runs at 50 miles an hour and there is no wind, or when it runs at 60 miles an hour and overtakes a 10-mile breeze that is blowing in the same direction. In each case the atmospheric pressure would be the same as if the wind were blowing at the rate of 50 miles an hour and the engine were standing still; and the pressure per square foot would be about 12½lb. In a similar manner, but with greater force, would the pressure of the atmosphere act on bullets in motion.

What may be the amount of pressure exerted by the air on moving projectiles was ascertained a few years ago by the Rev. F. Bashforth, Professor of Applied Mathematics to Royal Artillery Officers at Woolwich. He found, as the result of experiments carried out by order of the Government, that with a 14in. spherical shot (which is almost exactly one square foot in sectional area) the resistance of the air produces a pressure of rather more than a ton when the shot is moving with 1400ft. velocity; and that with a velocity of 1900ft. per second the resistance is increased to more than two tons per square foot. With shot of larger or smaller sizes, the pressure, with the same velocity, is proportionate to the amount of surface the projectiles present to the resistance of the atmosphere, and consequently would be at the rate of a ton or two tons per square foot on a spherical bullet, if moving at the speeds stated; but a 4-bore bullet would only be about the $\frac{1}{200}$th part of a square foot, and one of ·500in· diameter would be about the $\frac{1}{800}$th part of a square foot, and the pressure in proportion. No wonder, when they encounter such resistance as this, that projectiles of all kinds fall off in velocity as they pass through the air.

With bullets of light weight the loss of speed is much more considerable than with heavy projectiles ; for shot of the same shape, and moving with equal velocity, meet with a resistance which, as just stated, is proportionate to the amount of surface they present to the atmosphere as they rush forward, whereas their weight, and consequent momentum, is by no means in equal proportion, but decreases at a much more rapid rate than their diminution of surface. Thus, the 14in. round shot just alluded to would weigh about 3½ cwt., and the air-resistance would have a much less retarding effect on so heavy a mass than it would have on a 4-bore bullet of about an inch in diameter, for the weight of the 14in. shot would be about 1600 times as great as that of the inch bullet, but its surface would only be about 200 times as great. In like manner, a pellet of No. 6 shot, which is about $\frac{1}{10}$th of an inch in diameter, would be more retarded than the 4-bore bullet. Such a bullet is heavier than a thousand pellets of No. 6 shot, whereas its area of resistance is barely a hundred times as great; and while the air-resistance would depend on the diameter, the momentum, or, in other words, the "staying power" of the respective projectiles, would be proportionate to their weight. Hence, the 14in. cannon ball, with 1400ft. initial velocity, would only lose about 20ft. of its speed in the first 50 yards; and the 4-bore bullet would fall off about 150ft. in velocity in a like distance; whereas a No. 6 pellet would soon be reduced to less than half of its original speed, for if it started with a velocity of 1400ft. per second, it would, after travelling 50 yards, have little more than 600ft. velocity remaining.

Were it not for this resistance of the atmosphere, small shot would not lose speed any faster than large ones, nor spherical balls more rapidly than elongated bullets. Indeed, there would be no loss of speed at all in projectiles fired horizontally, for they would simply be drawn down towards the earth by force of gravity. When fired in a direction away from the earth they would be reduced in velocity during their ascent, owing to the retarding influence of gravitation; but the decrease would be a comparatively slow process, and the speed lost in the rise would be regained in the fall. Under such circumstances, a ball fired vertically into the air with 1400ft. initial velocity, would, whatever its weight and shape, ascend to a height of more than 30,000ft., or about six miles; and in its descent it would acquire the same velocity that it had on leaving the muzzle of the gun. Under existing conditions, however—encountering, as it does, the resistance of the atmosphere—a bullet with the initial velocity just mentioned might not rise to a quarter, a tenth, or a twentieth part of the above-named distance; and the height of the ascent would vary with the weight and shape of the projectile. In the descent, too, the shot would again encounter the resistance of the air, and instead of re-acquiring the speed it had on leaving the gun, it would reach the ground with a comparatively low velocity. It is stated, indeed, that the utmost velocity attained by the old-fashioned musket-ball during its descent to the earth, after being fired high up into the air, was but little over 200ft. a second; for the resistance of the atmosphere suffices to prevent any increase of velocity beyond a certain point, when a body descends by the mere force of gravity; but that point would not be alike with all projectiles, as it would depend upon their weight and dimensions, and consequent power of overcoming resistance.

## THE FORM OF THE BULLET.

The shape of the bullet has a very great deal to do with the amount of resistance it encounters in making its way through the atmosphere. Spherical shot are ill-fitted for maintaining their velocity — first on account of the large amount of surface in proportion to weight (especially in small projectiles), and, secondly, because they are badly formed for thrusting their way through the air. Elongated shot have much more weight in proportion to the extent of surface directly opposed to atmospheric resistance, and in such projectiles, therefore, one objectionable quality appertaining to spherical balls is got rid of; but if the head of the elongated projectile be shaped like the half of a round ball, the second objectionable feature above alluded to is retained, and an elongated bullet with hemispherical head will encounter considerably more resistance from the air than will another bullet similar in size but better in form. In the hemispherical bullet there is a "bluffness" that reminds one of the full, broad bows seen in old-fashioned slow-moving sailing vessels; and as we know that the speed of ships depends largely upon the "lines" on which they are built, so do we find the velocity of the projectile influenced by its shape. In the one case as in the other, the amount of resistance is determined, not merely by the bulk and speed of the moving body, but also by the lines or curves which that body presents to the fluid through which it has to force its way.

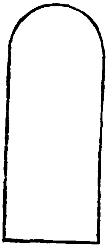
FIG. 7.

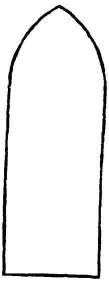
FIG. 8.

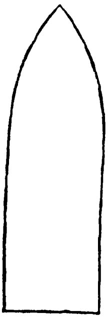
FIG. 9.

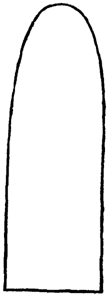
FIG. 10.

In the above figures are shown sections of several half-inch or ·500-bore bullets, which differ in the shape of their heads, but are alike in the body, being two diameters (or one inch) each in length, independently of head. In Fig. 7 the head is hemispherical; in Fig. 8 and Fig. 9, both heads are ogival in shape (like the pointed windows and arches of Gothic buildings), though they differ in their curves, which are formed on a radius of one diameter in the former case and of two diameters in the latter. In Fig. 10, the curvature at the shoulder is similar to that in Fig. 9, but the point being rounded off, it becomes elliptic, or, rather, hemispheroidal at the end. The bullets are shown with equal length of body, in order that the difference in shape of the head may be more obvious; but, of course, if the bullets had to be made of equal weight, the body of the longer bullets would have to be somewhat shortened.

Bullets shaped like Fig. 7 encounter considerably more air-resistance than do those formed like Fig. 8 or Fig. 9. The difference between the latter two is but trifling as regards resistance, although one is more sharply pointed than the other; and it is a curious fact, too, that the removal of the point has very little influence on the atmospheric resistance, which depends less on the sharpness of the bullet at the apex than on the nature of the curvature at the shoulder. Professor Bashforth found, as the result of experiments with elongated projectiles having heads of different shape, that the resistance to the hemispherical head (Fig. 7), at a velocity between 1100 and 1200 feet per second, was about 25 per cent. greater than with either of the other forms shown in Figs. 8, 9, and 10. He says: "The resistance to the hemispherical head was decidedly greater than that opposed to the remaining three forms. The resistance of the air to the hemispheroidal and the ogival heads varied so little that it was plain that any of these forms most serviceable in other respects might be safely adopted. The slight variations in the resistances to the three latter forms lead to the conclusion that the amount of resistance offered by the air to the motion of elongated shot is little affected by the more or less pointed apex, but depends chiefly upon the form of the head near its junction with the cylindrical body of the shot. In this neighbourhood the forms of the hemispheroidal head and the ogival head struck with a radius of two diameters are the same, and the resistances are little different."

Between the perfectly flat head and the hemispherical head there is not a very large amount of difference as regards air-resistance, though it is rather greater with the former than with the latter. It is strange, however, that with ordinary round shot there should be much more resistance than with elongated bullets having rounded heads, and more even than with flat-headed projectiles. It has just been stated that there is about 25 per cent. more resistance with bullets shaped like Fig. 7 than with the other shapes figured; and the resistance increases to about 30 per cent. with flat-headed projectiles; but with round shot the resistance is upwards of 40 per cent. more than with elongated shot like Figs. 8, 9, and 10, at the velocity previously stated, and at a lower velocity (1000ft. per second) it is about 90 per cent. more; for with change of speed the degree of the resistance does not alter in similar proportion with the different projectiles, as will be obvious from the following table, where the velocities range from 1000 to 2000 feet per second. Here the figures relating to 14in. round shot are included in order that the air-resistance on projectiles of this diameter may be regarded as "pressure per square foot," a 14in. circle being just about one square foot in area.

In the case of the bullets of ·500 bore, the last two columns will show the respective pressures on projectiles of half an inch diameter; but elongated bullets are, of course, much heavier than spherical balls of the same bore, and therefore, in order to indicate the proportion which the pressure bears to the weight of the bullet, a number is in each case placed between parentheses. Thus, in the first line, the pressure of the air on the ·500-bore elongated bullet is indicated as equal to about ten times the weight of the projectile, whereas that on the spherical ball of the same diameter is about forty times the bullet's weight. Hence it is that the spherical ball loses speed so much more rapidly.

### AMOUNT OF AIR-RESISTANCE AT DIFFERENT VELOCITIES:

| | With 14-inch Shot. | | With ·500-bore Bullets. | |
|---|---|---|---|---|
| Velocity. Ft.-sec. | Ogival. lbs. | Spherical. lbs. | Ogival. lbs. | Spherical. lbs. |
| 1000 | 456 | 859 | 0·58 (10) | 1·10 (40) |
| 1100 | 866 | 1227 | 1·10 (19) | 1·56 (56) |
| 1200 | 1153 | 1614 | 1·47 (26) | 2·06 (74) |
| 1300 | 1453 | 1977 | 1·85 (33) | 2·52 (91) |
| 1400 | 1794 | 2361 | 2·23 (40) | 3·01 (108) |
| 1500 | 2012 | 2755 | 2·57 (46) | 3·51 (126) |
| 1600 | 2238 | 3179 | 2·85 (51) | 4·06 (146) |
| 1700 | 2483 | 3613 | 3·17 (57) | 4·61 (166) |
| 1800 | 2745 | 4055 | 3·50 (63) | 5·17 (186) |
| 1900 | 3011 | 4539 | 3·84 (69) | 5·79 (208) |
| 2000 | 3351 | 5060 | 4·27 (76) | 6·45 (232) |

For the purpose of the above comparison with ·500-bore bullets, the elongated projectile has been assumed to be double the weight of the spherical ball. Thus, supposing the latter to weigh about 200 grains and the former 400, the air-resistance to the spherical ball would, at 1000 ft.-sec. velocity, be equal to nearly 40 times the weight of the ball, whereas with the elongated bullet it would be only about 10 times the weight of the projectile; and with higher velocities the pressure would go on increasing as shown by the respective numbers. If the elongated bullets were of more than double the weight of spherical balls of the same bore—as many are—the contrast would be still greater than is here shown.

### DIFFERENCES OF BAROMETRICAL PRESSURE.

It was intimated in a previous page that difference of barometrical pressure has, in some cases, a considerable effect on the amount of retardation produced by the air, and consequently on the extent of the "drop" in the bullet; and the longer the range and the lower the velocity, the greater this difference will be, while with short ranges and high speed the effect will scarcely be noticeable. Spherical balls are more sensitive to the change than elongated projectiles, and heavy bullets less so than light ones. Reference has been made in a previous page to two sportsmen who went on a shooting excursion across the Himalayas into Thibet, and who found great difficulty in hitting their game in the hill country; and, as already remarked, it seems probable that the result may have been due in some measure to the difference of the drop of the bullet in a rarefied atmosphere. What the greatest height was at which these gentlemen used their rifles is not apparent from the account of their doings. They ascended to the height of about 20,000 feet, yet it is not probable that they continued to shoot up to that elevation; but as mention is made of kakur or barking deer being found up to the height of 10,000 feet, and musk deer up to 12,000 feet, and of the party having gone in pursuit of tahr, or wild goat, at greater elevations, it may well be presumed that they used their weapons where the barometric pressure was less than 20 inches, which would be at about 11,000 feet high.* The "highest inn in Europe," on the Riffelberg, in the Alps, in the neighbourhood of the Matterhorn, is about 8500 feet high; and at this height the barometer would mark about 22 inches—a fact which may perhaps be of some little interest in connection with this subject, as chamois are still to be found in the district.

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* Since the above was written, two letters have appeared in the *Times* (Sept. 13, 1883), descriptive of mountain-climbing in the Himalayas, by Mr. Graham, a member of the Alpine Club, with two Swiss attendants. Writing from a camp at an elevation of 14,000ft., he says: "Boss is shooting. There is not much sport, but I was lucky enough to get a fine ounce or snow leopard. The peak Kang La, which Imboden and I ascended, is either 20,300ft. or 20,800ft., according to the two known surveys; so that I shall not return quite empty handed." And in the second letter Mr. Graham said: "We managed to bag another peak, which I have taken the liberty of calling Mount Monal, on account of the quantity of these fine birds on its lower slopes. Height, 22,326ft. by Government survey."

The reduction of barometrical pressure has a very similar influence upon the motion of the projectile to that which would be produced under ordinary atmospheric conditions if an addition were made to the weight of the bullet without enlarging its area or lessening its initial velocity. Under such circumstances a less amount of retardation would result from the resistance of the air. A fall in the barometer from 30in. to 29in. would be like multiplying the number of grains in the projectile by $\frac{30}{29}$, or, in other words, increasing it by $\frac{1}{29}$th of its weight; thus, in the case of the Martini-Henry bullet, raising it, in effect, from 480 grains to about $496\frac{1}{2}$ grains. And if the barometric pressure diminishes to 20in., the effect would be similar to multiplying the bullet's weight by $\frac{30}{20}$, and thus increasing it by one-half, which would be similar to an increase of the Martini-Henry bullet from 480 up to 720 grains. Such, indeed, is the likeness of result, whereas the difference in cause is, that in the one case less obstruction is offered by the reduced weight of the air, and, in the other, that the power of overcoming obstruction is enhanced by the increased weight of the bullet.

The modern "Express" rifle has considerably altered the condition of things from what they were formerly; and there is nowadays much less necessity for the exercise of a discriminating judgment than there used to be when none but spherical balls were in vogue. As the Himalayan excursion already alluded to took place some twenty years ago, the rifles used were not "Expresses," and the spherical balls employed were by no means of large dimensions. The rifle carried by the writer of the narrative was only a 24-bore (almost exactly the same diameter as the ·577 Express), which, with a spherical ball, must necessarily have had a very high trajectory at the long ranges at which it appears to have been used by him; and its susceptibility to differences of atmospheric pressure must have been considerable accordingly. If this rifle gave an initial velocity of, say, 1500ft. per second, its bullet would, in a range of 200 yards, drop about 1½in. less for every inch of fall in the barometer. Supposing, then, that these sportsmen were shooting at such an elevation that the atmospheric pressure indicated on the barometer was reduced from 30in. to 20in., and that their rifles had been sighted in England, where 30in. is the normal height of the barometer, the 24-bore bullet, after a flight of 200 yards through the air, would be about 15in. higher than the spot aimed at, so that a bullet which, under ordinary circumstances, would have killed or wounded an animal, might pass clean over its back in consequence of the diminished resistance of the atmosphere.

At short distances, however, the variations of drop from this cause are so small as to be practically unnoticeable, especially with heavy elongated projectiles; but even with these the differences are more marked as the distances increase, and at long ranges they become very considerable. The difference may be said, in round numbers, to increase in proportion to the cube of increase in range, so that if the bullet were an inch high at one distance, it would be about 8in. high at double the distance. With heavy elongated bullets, such as the Martini-Henry, the proportion keeps very near to the cube; with spherical balls there is a greater ratio of difference, as will be seen by the following figures:

DIFFERENCE IN DROP OF BULLETS WITH 1 INCH DIFFERENCE IN BAROMETER (29″ AND 30″).

| | At 100yds. | At 200yds. | At 400yds. | At 800yds. |
|---|---|---|---|---|
| Martini-Henry, with 1350 ft.-sec. muzzle velocity | 0·04in. | 0·34in. | 2·6in. | 22in. |
| 24-bore spherical ball, with 1500 ft.-sec. muzzle velocity | 0·17in. | 1·61in. | 15·7in. | ... |

### DIFFERENCE IN DROP WITH 10IN. DIFFERENCE IN BAROMETER (20″ AND 30″).

| | At 100yds. | At 200yds. | At 400yds. | At 800yds. |
|---|---|---|---|---|
| Martini-Henry, with 1350 ft.-sec. muzzle velocity | 0·43in. | 3·6in. | 2ft. 2in. | 17½ft. |
| 24-bore spherical ball, with 1500 ft.-sec. muzzle velocity | 1·70in. | 15·4in. | 13ft. 0in. | |

It will be observed that, with every doubling of distance, the difference with the Martini-Henry bullet increases in about an eightfold degree, whereas with the spherical ball it is even greater, the increase being tenfold or thereabouts; and although, when the barometer falls from 30″ to 29″ (which might happen in the course of a few hours in these islands), the 24-bore bullet would show only about ⅛in. greater variation than the Martini in 100 yards, yet the augmentation is so rapid that the difference in the height of the spherical ball at 400 yards would exceed 15in., although in the case of the long bullet it would be less than 3in. With the great reduction in barometrical pressure that occurs in high mountain regions the differences increase accordingly. Thus, at the height of about 11,000ft. (where the barometer marks only 20″ instead of 30″) the bullet loses no more velocity in traversing 300 yards of this attenuated air than it would in passing through 200 yards of the heavier atmosphere near the sea level. Consequently, about ten times as much effect is produced by the 10in. reduction on the barometer as by the 1in. fall previously alluded to; and in 400 yards the difference with the 24-bore spherical ball would amount to about 13ft., so that the bullet which would strike less than 1½in. high at 100 yards would increase the difference in height more than ten times for every doubling of distance. Obviously, it would be useless to give the difference with the spherical ball in ranges beyond 400 yards.

*It may probably be said that nobody would think of firing at game 400 yards off with a 24-bore spherical ball.* These particular remarks, however, are not intended to demonstrate what would be done nowadays, but to illustrate principles that are still in force by striking examples of what was done in days gone by; and the writer quoted said, in one part of his narrative, after alluding to game found at elevations up to 11,000ft.: "I amused myself with three long shots at a gooral, who was feeding about 400 yards off, down a khud, but missed him. . . . . He could not see me, and, on the first two shots being fired, seemed not to understand it at all. . . . . The third bullet, hitting the ground close to his feet, roused him from his fancied security, and away he bounded out of sight. This animal was probably much farther off than I have stated; for distance is so deceptive in mountainous ground, and I should not have seen him at all if I had not discovered him with the aid of my binoculars."

Elongated projectiles, more especially heavy ones, are affected much less than spherical ball; but the following figures will show the regularity of increase in velocity and diminution in drop of a Martini-Henry bullet in a 1000-yards range, with each successive reduction of an inch in the barometric scale. The last column shows the consequent rise of the bullet above the mark aimed at, supposing the elevation of the rifle to be equal throughout. The initial velocity of the bullet is taken at 1350 feet per second, and the third column shows the remaining velocity at the end of the 1000 yards range. A text-book issued by Government for officers at the School of Musketry gives the muzzle velocity of the Martini-Henry as 1365 ft.-sec.; but various chronograph records have not greatly exceeded 1300, so that 1350 is taken as an intermediate round number.

| *Barometer.* | *Height above sea-level.* | *Velocity of bullet at 1000 yards.* | *Drop of bullet in 1000 yards.* | *Height of bullet above mark.* |
|---|---|---|---|---|
| 30in. | 0 | 672 ft.-sec. | 186·0 feet | 0 |
| 29 | 841 feet | 684 „ | 182·1 „ | 3·9 feet |
| 28 | 1832 „ | 696 „ | 178·3 „ | 7·7 „ |
| 27 | 2859 „ | 708 „ | 174·6 „ | 11·4 „ |
| 26 | 3926 „ | 720 „ | 171·0 „ | 15·0 „ |
| 25 | 5033 „ | 733 „ | 167·3 „ | 18·7 „ |
| 24 | 6186 „ | 746 „ | 163·6 „ | 22·4 „ |
| 23 | 7389 „ | 759 „ | 160·1 „ | 25·9 „ |
| 22 | 8644 „ | 773 „ | 156·7 „ | 29·3 „ |
| 21 | 9958 „ | 787 „ | 153·3 „ | 32·7 „ |
| 20 | 11336 „ | 801 „ | 150·0 „ | 36·0 „ |

Express rifles vary so much in the velocity and weight of their projectiles, and the atmospheric resistance alters so greatly in ranges of different length, that a very extensive series of tables would be required to set forth the relative effect of changes in barometrical pressure with Express bullets differing in size, weight, and speed; but sufficient has been said to show that, at ordinary sporting ranges, with our modern weapons, the reduction of weight in the atmosphere affects the drop of the bullet only to the extent of inches, where formerly the difference amounted to feet.

It may be as well, however, to give the following two as typical examples; but the inch-by-inch variation differs so little from the mean of 10in. that it is not thought necessary to give the figures throughout:

DROP OF EXPRESS BULLETS AT DIFFERENT BAROMETRICAL PRESSURES.

·450 BORE; 260GR. BULLET; 1900 FT.-SEC. MUZZLE VELOCITY.

| Height of Barometer. | Drop of Bullet in | | | | |
|---|---|---|---|---|---|
| | 100yds. | 150yds. | 200yds. | 300yds. | 400yds. |
| 30″ | 6·09in. | 15·50in. | 31·25in. | 88·96in. | 191·51in. |
| 29″ | 6·03 | 15·31 | 30·71 | 86·90 | 187·06 |
| | ...... | ...... | ...... | ...... | ...... |
| 20″ | 5·62 | 13·69 | 26·43 | 70·26 | 146·89 |
| Total reduction in 10″ | 0·47in. | 1·81in. | 4·82in. | 18·70in. | 44·62in. |
| Mean reduction per 1″ | 0·05 | 0·18 | 0·48 | 1·87 | 4·46 |

·450 BORE; 360GR. BULLET; 1600 FT.-SEC. MUZZLE VELOCITY.

| Height of Barometer. | Drop of Bullet in | | | | |
|---|---|---|---|---|---|
| | 100yds. | 150yds. | 200yds. | 300yds. | 400yds. |
| 30″ | 8·09in. | 19·89in. | 38·58in. | 101·94in. | 207·01in. |
| 29″ | 8·04 | 19·72 | 38·12 | 100·44 | 203·60 |
| | ...... | ...... | ...... | ...... | ...... |
| 20″ | 7·63 | 18·25 | 34·35 | 86·74 | 172·24 |
| Total reduction in 10″ | 0·46in. | 1·64in. | 4·23in. | 15·20in. | 34·77in. |
| Mean reduction per 1″ | 0·05 | 0·16 | 0·42 | 1·52 | 3·48 |

It will be seen that at 100 yards the reduction of drop is almost exactly the same with both bullets; but on comparing 100 with 200 yards, 150 with 300, and so on, it will be found that the rate of reduction proceeds more rapidly with the lighter projectile, there being in double the distance more than a ninefold difference with the 260gr. bullet, and little over eightfold with the 360grs.; and at 400 yards the latter is about seventy times greater than at 100 yards, while the former is about ninety times greater. The light bullet suffers most from air-resistance at high barometrical pressures, and consequently receives most advantage from their diminution, and the result is shown in its flying higher than the heavier bullet of the same bore.

There is another way, too, in which atmospheric resistance affects bullets, though not in a great degree such as are used for sporting purposes. As stated in page 61, bullets are retarded by the air when falling towards the earth; and this especially affects the drop of those fired at very long ranges. The time of the Martini-Henry for 1000 yards is nearly 3½ seconds; in that time the velocity of descent would exceed 100 feet per second, but the more rapid the drop becomes, the greater is the resistance encountered, so that the projectile is to some extent, buoyed up by the air during its descent. This would operate on light bullets to a greater extent than on heavy ones if the range were equal, and would tell most on those that have great length in proportion to diameter. Sporting weapons, however, are seldom fired at distances that take more than a second for the bullet to traverse; and the air-resistance in a drop of one second would not be a tenth part of that which occurs in a drop that lasts for 3½ seconds.

Temperature and moisture are other causes of variation in the weight of the air, and consequently alter the amount of resistance it offers to the passage of the bullet. Fortunately, however, in many cases the alteration due to temperature tends to counteract the alteration due to elevation. In high mountain ranges the barometrical pressure diminishes, and so does the temperature; but the weight of the air is increased by the latter and decreased by the former. This subject, however, will be further alluded to in the chapter relative to the estimation of trajectories, as likewise will that of moisture in the atmosphere.

The force of the wind also has an influence on the drop of the bullet. It is commonly said that a head wind "beats the bullet down," whereas a wind from the rear "drives the bullet up." These expressions, however correct they may be in the sense of the bullet being placed higher or lower on the target, are apt to mislead as to the cause of the difference of position. The "beating down" is not to be taken in its strictly literal acceptation, but as representing the effect produced by a lessening of the speed of the bullet—in consequence of which it takes a longer time to traverse a given distance; and the longer the time the greater is the amount of drop, as already explained. The wind from the front or rear produces, indeed, a somewhat similar effect to a rise or fall in the barometer: it increases or diminishes the amount of resistance encountered by the bullet, and thus, by affecting its speed, indirectly lessons or increases the drop. Let us suppose, for example, that a bullet has a mean velocity of 1200ft. in a

400-yards range: it would thus take just one second to traverse the distance, if there were no wind. If, however, there were a head wind, the bullet would be delayed in proportion to the wind's velocity. One mile an hour is equal to rather more than 17½in. a second; and, taking half a yard per second as a round number, a wind of twenty miles an hour would be equal to 10 yards a second. A bullet meeting with such a head wind would be retarded to the extent of about 10 yards in the 400-yards range above mentioned, and consequently would take rather more than a second to traverse the distance; whereas, if it had a rear wind of the same velocity, it would do the like distance in rather under a second. The effect would be similar to increasing the range to 410 yards in the one case, and reducing it to 390 in the other, if there were no wind. The difference may seem small, but the drop, as already stated, is in proportion to the "square" of the time, and the difference between the two positions of the bullet would be about 19in.; the one being about 9½in. above and the other about 9¾in. below what it would have been had there been no wind. In a range taking double the time, the difference would be increased fourfold; in one of half the time there would be only a fourth of the difference, and so on. Hence (if we assume the mean velocity to be equal in each case) there would be in 100 yards a variation above or below of little more than half an inch; but in 1000 yards the variation would be about 5ft. each way. This is on the supposition that the wind has a velocity of twenty miles an hour. If the velocity were but ten miles an hour, the difference of drop would be but half as much; and so with other wind velocities. Moreover, the supposition here is that the mean velocity of the bullet is uniformly 1200ft. per second; but every bullet having a different velocity would require a different estimation, and as all bullets lose speed during their flight, there would be some amount of variation with every change of distance.

# CHAPTER V.

## PRODUCTION OF MOTION BY COMBUSTION OF POWDER.

The motion of projectiles is often spoken of as though it were produced instantaneously. Such, however, is not the case; for, brief as may be the period of time occupied in imparting motion to the bullet, its velocity is acquired by a process of gradual development, in much the same way as the speed of the railway train already alluded to; and, in like manner as there are differences in the rate of "getting up speed" in engines constructed for heavy goods trains and those made for the short quick spurts between metropolitan passenger stations, so is the speed attained differently in fire-arms constructed for different purposes and used with powders of different make.

Those powders that evolve their gases slowly, by reason of highness of density or largeness of grain, impart speed slowly to the mass they have to impel; while powders that are small in grain, or light and porous, ignite more rapidly, and, by a quicker evolution of gas, put greater immediate pressure on the projectile, which accordingly is driven at higher speed for the time during which the pressure lasts. Anyone can see, in a small way, the difference of action between fine and coarse powder by casting a pinch or two upon a fire. That of fine grain flashes up briskly the instant it touches the red-hot coals; the large grain goes off comparatively slowly and lazily; while the coarse-grain punt-powders are rather surprising in the length of time they take before they puff off. I have found some of the coarsest grain refuse to ignite by the mere application of a lighted match, just as lumps of coal remain unignited by burning sticks that suffice to inflame the same coal in smaller fragments.

If the greatest amount of impulse from equal quantities of powder were alone to be considered, fine and light-grained powders should give the highest results, especially in the short barrels used for sporting purposes. But there are other matters also to be taken into consideration, not the least of which is danger; and that powder which puts most pressure on the shot will also put the greatest strain upon the barrel, and be more likely than any other to burst the gun.

The amount of force that may be developed by the gases of burning gunpowder is so immense that no ordinary small-arm barrels would withstand the strain if fully exerted. Among a number of experiments carried out at Woolwich, a few years ago, by Capt. Noble and Professor Abel (details of which have been published in the "Philosophical Transactions of the Royal Society"), were a series for the purpose of ascertaining the force of gunpowder when exploded in a closed chamber completely filled by the powder and strong enough to prevent any escape of the gases. Among the powders experimented on was Curtis and Harvey's well-known No. 6; and in this case the pressure was found to be equal to about 42 tons per square inch. In some of the Government powders the pressure was even higher than this.

In a loaded gun, a small portion of the barrel is completely filled with powder; and if this powder, when fired, remained closely confined within that limited space, the gases would develope the pressure of more than 40 tons per square inch, irrespective of the size of the gun or the quantity of powder employed.

It may not unnaturally be asked, if such be the case, how it is that greater results are not obtained from charges of powder less than those generally used. There are, however, several reasons for this. In the first place it must be remembered that, although the powder may fill a given space in a gun, it is not, as a matter of fact, closely confined; for the chamber in which the powder is fired undergoes continued enlargement through the movement of the shot, when once the gases have developed force enough to set the projectile in motion. Thus, 3drs. of powder occupies less than an inch of the barrel in a 12-bore gun; but before the shot leaves the muzzle, the gases have expanded into a space more than thirty times as great as that which the powder originally occupied. Prior to the shot moving from its position, its base, or portion bearing on the powder, forms about $\frac{1}{7}$th of the area on which the gases exert their pressure; but when the shot gets to the other end of the barrel, its base represents less that the $\frac{1}{200}$th part of the area on which the gases press. And this is not all the difference between the powder gases which are able to expand and those which cannot do so. The more closely they are confined, the greater is the pressure they exercise; the greater the pressure, the greater is the heat developed; and the more intense the heat, the more expansive become the gases, and the larger is the amount of force which they exert; so that a repeated action and reaction goes on, increasing the pressure of the pent-up gases, until the whole of the powder is consumed. When, however, relief is given by the movement of the shot, such immense pressure does not ensue; consequently the heat does not become so intense, and accordingly, with less heat, the full expansive force of the gases is not developed.

The heat requisite to ignite the powder is very different from that attained by the confined gases. Black powder ignites at from 500° to 600° Fahr., according to various *authorities—the differences of record probably* arising from variations in the composition and make of the powder. The gases, however, attain a heat many times greater than that which suffices to ignite the mass, Professor Abel estimating the temperature at 2200° C. (about 4000° Fahr.), in which condition their expansive power would be enormously increased.

When the gases had been cooled down to 0° C. (32° Fahr.), their power of expansion was still sufficiently remarkable, for the "permanent gas" then remaining was found to fill, at ordinary atmospheric pressure, about 280 times the space occupied by the powder before it was ignited. In other words, the cooled gas, while shut up in the chamber in which the powder had been burnt, exerted a pressure 280 times as great as the pressure of the atmosphere; and, as the latter amounts to nearly 15lb. per square inch, the force of the gas would be equivalent to a pressure of about 4200lb. per square inch. And this, be it remembered, was the force of the gas when cold. But the volume of gases is increased with rise of temperature, and that which would occupy one cubic foot of space at 0° C. would fill two cubic feet at 273° C. (nearly 500° Fahr.), and there would be a similar increase for each corresponding rise of temperature ; so that the powder-gas which exerts a pressure of 4200lb. when cold, will, when heated to 2200° C., give a pressure of about 38,000lb. or 17 tons to the square inch.

This, however, still falls far short of the 42 tons pressure previously mentioned; but we must not lose sight of the fact that the chamber in which the powder was burnt would not be filled by gases alone. There always is some amount of fouling in the gun after it has been fired, although the greater portion of the solid residue is carried away when the gases make their exit from the muzzle. But when powder is burnt in a closed chamber strong enough to withstand the pressure, the whole of this residue (which, when intensely heated, is in a fluid state) is preserved, and solidifies in the chamber as it cools; and Professor Abel found that the residue amounted to nearly 60 per cent. of the entire weight of the powder originally put into the chamber, and occupied nearly three-fifths of the space. Making, then, due allowance for this, we shall find the pressure brought up to about 6500 atmospheres, or the 42 tons already stated.

It is obvious, therefore (even if we were disposed to allow a considerable margin for possible error), that the charges fired from our sporting guns and other small arms must contain an immense amount of potential force which remains undeveloped under ordinary circumstances. Occasionally, however, by some check on the prompt movement of the projectile, this may be brought into operation, and result in the bursting of a barrel that is strong enough to meet the pressures to which it is usually submitted, but cannot withstand the extra strain which results when the powder gases do not get their accustomed relief. And when anything thus prevents the movement of the shot, small arms doubtless give way long before the maximum pressure is reached, because nothing but the strongest ordnance could possibly withstand the strain; and the gases will always force their way out by the line of least resistance—whether it be by pushing the shot onwards throughout the bore, or by driving a piece out of the weakest part of the barrel.

Under some circumstances, however, when there is no unusual obstruction to the passage of the shot, there appears to be a very peculiar action on the part of quick-burning powder, which gives rise to a much greater pressure than that which is ordinarily produced by the very same powder. Possibly this may account for guns occasionally bursting without apparent cause, after many similar charges have been fired with impunity. Messrs. Noble and Abel give some interesting particulars on this point. They explain, in their paper in the "Philosophical Transactions," the means they had adopted to ascertain the amount of pressure produced by different powders. One method was to take the pressure directly by the crusher-gauge, and another was to estimate it indirectly by calculating the amount of force requisite to impart to the projectile the velocity which the chronoscope showed to exist at different points of the barrel as it passed from breech to muzzle. Of course, if a shot of a given weight be moved from a state of rest for one or more inches in a certain fraction of a second, a definite amount of force would be required to effect such movement in that period of time; and if the shot, when in motion, were carried so many inches further in another period of time, the additional speed imparted would also show what amount of pressure must have been exerted in that section of the barrel; and so on throughout the whole length of the bore. In each of these sections the pressure thus estimated would be the mean pressure for the very short space of time during which the shot was passing from point to point, and consequently it would be somewhat less than the maximum pressure exercised. Under ordinary circumstances, however, the two modes of estimation appear to have approximated very closely, but occasionally pressures were set up that were far higher even than those produced by powders closely confined within the space they occupied. Messrs. Noble and Abel make the following remarks on this subject:—

"With powders where a slow and tolerably regular combustion takes place, the maximum tension of the gas, obtained both by direct measurement and by the chronoscope, agrees remarkably closely. There is generally a very slight difference indeed between the indicated pressures; but the case is greatly different where the powder is of a highly explosive or quickly burning description. In such a case, not only are the pressures indicated by the crusher-gauge generally much above those indicated by the chronoscope, but they differ widely in various parts of the powder-chamber, in the same experiment, and even in different parts of the same section of the bore. *They are also locally affected by the form of the* powder-chamber, and frequently indicate pressures considerably above the normal tensions that would be attained were the powder confined in a close vessel.

It is not difficult to explain these anomalies. When the powder is ignited comparatively slowly and tolerably uniformly, the pressure in the powder-chamber is also uniform, and approximates to that due to the density of the products of combustion. The crusher-gauges then give similar results throughout the powder-chamber, and they accord closely with the results deduced from the chronoscope observations. But when a rapidly lighting or "brisante" powder is used, the products of combustion of the portion first ignited are projected with a very high velocity through the interstices of the charge, or between the charge and the bore; and on meeting with any resistance their *vis viva* is reconverted into pressure, producing the anomalous local pressures to which we have drawn attention.

We have pretty clear proof that, when this intense local action is set up, the gases are in a state of violent disturbance, and that waves of pressure pass backwards and forwards from one end of the charge to the other, the action occasionally lasting the whole time that the shot is in the bore. In fact, with the rapidly burning, and in a less degree even with the slower burning powders, motion is communicated to the projectile not by a steady, gradually decreasing pressure like the expansive action of steam in a cylinder, but by a series of impulses more or less violent.

The time during which these intense local pressures act is of course very minute; but still the existence of the pressures is registered by the crusher-gauges. The chronoscopic records, on the other hand—which are, so to speak, an integration of the infinitesimal impulses communicated to the shot—afford little or no indication of the intensity of the local pressures, but give reliable information as to the *mean* gaseous pressure on the base of the shot.

The two modes of observation are, as we have elsewhere pointed out, complementary one to the other. The chronoscope gives no clue to the existence of the local pressures which the crusher-gauge shows to exist; while, on the other hand, where wave or oscillatory action exists, the results of the crusher-gauge cannot be at all relied on as indicating the mean pressure in the powder-chamber.

An interesting illustration of this distinction was afforded by two consecutive rounds fired from a 10-inch gun, in one of which wave-action was set up, in the other not. In both cases the projectile quitted the gun with the same velocity, and the mean pressure throughout the bore should of course have been the same. The chronoscopic records were, as they ought to be, nearly identical *for the two rounds; but the pressures indicated by the crusher-gauge were in the one round (at certain points indicated),* respectively 63·4, 41·6, 37·0, 41·9, and 25·8 tons on the square inch; in the other, at the same points, respectively 28·0, 29·8, 30·0, 29·8 and 19·8 tons on the square inch.

Where no wave-action exists, the chronoscopic pressures are generally somewhat higher than those of the crusher-gauge. The difference is not generally greater than about 5 to 7 per cent., although in the case of some exceptionally heavy shot, this variation was considerably exceeded. Among the causes tending to produce this difference may be cited :—1. Friction in the parts of the crusher-gauge. 2. Slight diminution of pressure due to the windage. 3. *Vis viva* of particles of the charge and products of combustion, a portion of which would be communicated to the shot, but would not take effect on the crusher-gauge.

On the whole, the accordance of results derived from methods so essentially different was quite as close as could reasonably be expected, and entirely satisfactory."

But besides the extreme amount of force that might possibly be developed under extraordinary circumstances, we have also to consider the variations of force which occur in guns under ordinary circumstances.

If we have gunpowders of the same composition fired in closely-confined chambers, the amount of force developed would be much more than sufficient to burst the barrels of small arms, whether the powder were large or small in grain, or high or low in density; the fact that one powder takes longer to burn than another would not prevent its developing as much ultimate pressure on the confining walls. Such, however, is not the case when the same powders are fired in a gun; for the large and dense grain would burn so slowly that the shot would be gradually pushed on and the chamber considerably enlarged before the bulk of the powder was consumed; and as the development of gas would chiefly take place after the shot had been set in motion, the pressure would not become so intense as when a quick-burning powder gives forth all or nearly all its strength before the shot *begins to move.*

A small persistent pressure will move an object as well as a much larger and more sudden application of force; but if you apply only a small force, you must continue the pressure for a longer period of time in order to obtain an equal result. Who has not seen an exemplification of this when a railway porter lays his shoulder against a truck several tons in weight and pushes for a while apparently to no purpose? At length, however, the continued pressure begins to tell, and the truck moves, very slowly at first, but gradually getting faster; and eventually the man walks onward with the truck at a tolerably smart pace. He removes the empty vehicle as effectually as an engine that runs against it with a strong bump, and gives a "kick off," which sets the truck running for some distance along the line. The work done by both is the same: the difference is in the time taken to do it, and also, no doubt, in the wear and tear of the machine.

So it is with gunpowders. If you have one that burns very slowly, it will move the shot in course of time, but with a sort of "hang-fire" process, which is immaterial with big guns and sitting shots, but is vexatious to the marksman wishing to hit birds and beasts in motion. If you have a very quick-burning powder, it will set the shot moving in the barrel in less time and with greater rapidity, but also with greater strain upon the breech of the gun; and yet, as the pressure is not maintained to an equal extent throughout the barrel, the shot may possibly leave the muzzle with no higher velocity than that imparted by a slower-burning powder, that gave less strain at first, but kept up its force for a longer *time, and so did the same amount* of work in the end. In some cases, however, a heavier charge of the coarse powder may be required to give the same velocity as that imparted by the small-grain powder; nevertheless, the small charge of the latter will put most strain upon the gun.

Another example of difference of time in the performance of work is to be found in coal, as compared with gunpowder. As is pointed out by Messrs. Noble and Abel, in their paper in the "Philosophical Transactions," there is more energy in a pound of coal than in a pound of gunpowder. The coal, in fact, will do a greater amount of work than the powder, but takes a longer time to do it. Propositions that have been made for the employment of gunpowder as a motive agent for machinery are therefore futile, though not merely from the difficulties arising out of its explosive character. An explosive mixture of coal-gas and air is employed to work gas-engines, and for some purposes is economical; but the cost of gunpowder is a hundred times as great as that of coal. A large portion of the cost of the powder goes to provide the oxygen requisite for its combustion; whereas, in the case of coal in a furnace, or coal-gas in an engine, an inexhaustible supply of oxygen is drawn, free of cost, from the atmosphere.

## THE STRAIN UPON THE GUN.

No systematic experiments have been carried out to determine the varying degrees of pressure in different parts of the same barrel in sporting guns, but with artillery there have been many such experiments; and those reported to the Secretary of State for War in 1870, by a Committee on Explosives, of which Colonel Younghusband, R.A., was president, afford a very good example of the difference of strain produced by different powders that gave nearly the same amount of velocity to projectiles of equal weight. The powders used were (1) the R.L.G. (rifle large grain), formerly in general use for cannon in our service; (2) the service Pellet powder, of larger grain; (3) Waltham Pebble powder, of still larger grain and higher density; and (4) Russian prismatic powder. They were all tried in the same gun—an 8in. muzzle-loader, with shot weighing 180lb. each; and the barrel was tapped at about twenty places, from breech to muzzle, so as to insert crusher-gauges and cutting plugs, for the purpose of testing the pressure on the breech and different parts of the barrel, and ascertaining, by means of the chronoscope, the velocity of the shot at various points before it reached the muzzle of the gun. Of course the pressures, with such heavy projectiles, are vastly greater than with the bullets used in small arms, but the velocities are not greater, and the pressures will afford a means of comparison between fast and slow-burning powders, which would be very similar in effect to those used in sporting weapons, though in the latter they are on a much smaller scale. The following will show the variations at equal distances of $\frac{1}{10}$th of a foot, or rather more than an inch apart, the first column representing the pressure (in tons per square inch) before the shot moves, and the others showing the rise or fall at subsequent points up to 1ft. from the starting point. The figures 1 to 4 in the first column indicate the four kinds of powder mentioned above.

PRESSURE IN TONS PER SQUARE INCH AT POINTS $\frac{1}{10}$FT. APART.

| Powder. | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 19 | 16½ | 15½ | 14½ | 14 | 13 | 12½ | 12 | 11½ | 11 |
| 2 | 2½ | 13 | 16½ | 17½ | 16½ | 16 | 15 | 14¼ | 13½ | 13 | 12½ |
| 3 | 1 | 5 | 11 | 14 | 15 | 15½ | 15¾ | 15 | 14½ | 14 | 13¼ |
| 4 | ¼ | ¾ | 2 | 7 | 20½ | 19½ | 17 | 15½ | 14½ | 13¾ | 13 |

It will be seen that with the smallest-grained powder (the first on the list) the highest pressure occurred before the shot moved, and then it diminished continuously. With all the others the pressure went on increasing for some inches before it attained its highest point; and the powder which gave its maximum pressure farthest from the breech was the one which put least strain upon the gun. The muzzle velocities imparted by these four powders were—1st, 1324 feet per second; 2nd, 1338; 3rd, 1374; and 4th, 1366. The weight of powder was not equal with the whole of them; those which gave the lowest initial pressures had the heaviest charge—No. 3 having 35lb. and No. 4 32lb., as against 30lb. with each of the other two.

As already stated, the figures in the foregoing table represent the different pressures in the space of 1 foot. From that point the strain gradually diminished throughout the barrel in every instance, so that, 6ft. further on, No. 1 gave only 1 ton pressure; No. 3 was highest, with 1½ tons; and Nos. 2 and 4 nearly equal, at about 1¼ tons.

When the projectiles are small, as in sporting rifles, they begin to move under pressures that are very light in comparison with those mentioned above, so that space is quickly afforded for expansion of the gas; and the more readily this relief comes, the less is the advance made towards the 42-ton pressure which would result from an absolute fixture. When the shot moves freely, not only is the gas allowed to pass into a cooler portion of the barrel, but the expansion likewise tends to keep down the heat, and thus limits the force indirectly as well as directly. The heavier the projectile, the greater will be the resistance to the expansion of the quickly-evolved gases, which accordingly will become more heated under the pressure and rendered more expansive by the heat. Hence the danger of using very fine-grained or quick-burning powders with heavy projectiles, and the consequent necessity of making big blocks of slow-burning powder for use with the heavy ordnance of the present day.

How intimately pressure and time are connected will be seen by the following figures, which show the amount of time occupied by the before-mentioned powders in driving the shot the first foot in the barrel—the 12 inches being divided in two spaces of 2in. each and two of 4in. each ; and, for the sake of further comparison, times are also given at the two chronograph plugs that were nearest to the muzzle of the gun.

Distances and Times of Experiment on Page 85.

| Powder. | 2 inches. | 4 inches. | 8 inches. | 12 inches. | 6 feet. | 7ft. 4in. |
|---|---|---|---|---|---|---|
| 1 | ·0005 sec. | ·0008 sec. | ·0013 sec. | ·0018 sec. | ·0058 sec. | ·0073 sec. |
| 2 | ·0011 „ | ·0016 „ | ·0022 „ | ·0027 „ | ·0067 „ | ·0083 „ |
| 3 | ·0026 „ | ·0033 „ | ·0040 „ | ·0045 „ | ·0086 „ | ·0101 „ |
| 4 | ·0055 „ | ·0071 „ | ·0080 „ | ·0086 „ | ·0126 „ | ·0141 „ |

No. 1, which showed by far the highest pressure in the previous table, also sets the shot in motion much more quickly than the others ; but this superiority is very fleeting. At the end of only 12 inches there is already a considerable change of proportion ; and for the remaining part of the barrel the times are nearly equal. By taking the relative times at 6ft. and subtracting them from those at 7ft. 4in., it will be found that the speed given by the four powders is almost identical in these 16 inches—the time for this distance being ·0015 sec. with three of them, and ·0016 with the other one. The difference in the total times is, on the contrary, very remarkable, especially with No. 4, which takes about twice as long as No. 1 to drive the shot to the muzzle of the gun ; so that, in one sense, it must hang fire to an extraordinary extent. Yet these slow-burning powders make up their leeway before they quit the barrel. At the latest point indicated (7ft. 4ft), Nos. 3 and 4 are already moving quite as fast as Nos. 1 and 2, while No. 3, having left in it the greatest remaining force, is now imparting more velocity than the rest, and will have the highest speed of all at the muzzle.

### EFFECT OF TIME IN MODIFYING FORCE.

A very interesting example of the influence of time in modifying the effect of widely-different degrees of force occurred in the course of experiments carried out during the "*Field* Trial of Explosives" at Wimbledon, in 1878. Besides testing samples of black and wood gunpowder with a number of guns at the target, Mr. Walsh, who, as Editor of the *Field*, instituted these trials, endeavoured to ascertain the difference of strain exercised on guns by the various kinds of powder. For this purpose, he devised an apparatus consisting of a strong gunbarrel, fitted with a movable breech-plug, which, being driven back by the firing of the charge, acted on a lever connected with a powerful spring-balance, and registered the effect on the scale of the balance.

This apparatus demonstrated clearly enough that there were very wide divergencies in the amount of force exercised by the different powders, as compared with one another, but no satisfactory formula was forthcoming that would translate the differences on the scale into pounds of pressure. Among the methods tried was one which proved the precursor of the "*Field* force-gauge" (illustrated in the frontispiece, and described in page 36, of the first volume of this work), viz., that of dropping weights from a given height, noting the effects produced on the movable breech-plug and spring-balance, and comparing the results with those obtained by firing charges of powder and shot.

In the course of these experiments it was found that a 7lb. weight, dropped a distance of 1 foot, and transferring its force to the breech-plug, registered on the scale of the balance a very similar effect to that produced by the discharge of 3 drs. of No. 6 powder with 1⅛oz. of shot.

Such a result was rather startling, and was received with a good deal of incredulity, until constant repetition showed that it occurred again and again. An opportunity of making a comparison in another way fortunately presented itself, as Messrs. John Hall and Son, the well-known powder manufacturers, placed at the Editor's service a force-gauge they had made for their own use. This was constructed on the same principle as the "crusher-gauges" employed in artillery experiments—copper disks being used, which are compressed by the force of the powder; and, according to the degree of compression undergone by the disk, an estimate is formed of the amount of pressure exercised. By means of this apparatus it had been estimated that 3drs. of coarse-grained powder exerted a pressure of about 2000lb. per square inch on the breech of the 12-bore gun in which it was fired, and that with powder of fine grain the strain was nearly doubled.

The difference between the dropping of a 7lb. weight in the one case and the record of 2000lb. pressure in the other seemed so remarkable, that Mr. Walsh determined to try the direct effect of the falling weight upon the copper disks, and on dropping the 7lb. a distance of 1 foot, as before, the disk was found to be compressed to about the same extent as by firing the charge of 3drs. powder with 1⅛oz. shot. Confirmation was thus given of similarity of pressure on the two gauges; but the difference between the actual weight dropped and the estimated force imparted seemed to be so irreconcilable that it was not unnaturally concluded that "there was something wrong somewhere." The anomaly, however, was more apparent than real, and resulted from *time* being left out of consideration. Allowing for this, the differences are not so irreconcilable as they may appear at first sight.

As in the case of the railway truck recently alluded to (page 83), so with other bodies, motion is imparted by the application of a small or a large amount of force for a long or a short period of time—the velocity imparted by a given force being proportionate to the length of time during which the force is applied. On the application of double the force, a given velocity will be acquired in half the time; and any greater increase of force would cause a corresponding reduction of time—resistance from air and friction being for the present disregarded. On the other hand, when a body is in motion, as much power would be required to stop it as was necessary to impart the momentum possessed. If the force applied be the same in both cases, it would take as long to stop it as to get up equal speed; if stopped in a tenth or a hundredth part of the time, ten or a hundred times as much force would be requisite.

In the case of the falling weight, we know it would take a quarter of a second to fall a foot; but we do not know what time was taken by the apparatus in stopping the weight which had fallen that distance. But, whereas the weight dropped 12 inches, the breech-plug only recoiled a fraction of an inch. If we knew the exact fraction, we might estimate the time of motion and the consequent resisting force, although the question is complicated by the spring-resistance being an increasing and not a constant pressure. We may be sure, however, that the resistance was considerably greater than the mere 7lb. dropped, or the weight would not have been stopped in less than 12 inches, *i.e.*, the distance which it fell.

Let us see, then, whether we cannot estimate the force that must necessarily be applied to produce the velocity which was imparted to the shot.

There was a charge of 1⅛oz. of shot, which, in the length of a 30in. barrel, had acquired a velocity which we may take to be equal to about 1200 or 1300 feet per second when it reached the muzzle. Starting from the velocity 0 and finishing at, say, 1250, the mean velocity would be 625. And with a mean velocity of 625 ft.-sec. throughout 30 inches, the time of travel for this 2½ feet would be ·004 sec. (The pressure is assumed to be equal throughout the barrel, because it not only simplifies the calculation, but shows the lowest strain in the performance of the work; for an unequal force, although it may give the same mean pressure as a constant force, must produce greater strain at some points as well as be under the average at others; and we are here endeavouring to ascertain what is the *least* amount of strain with which the work could be effected).

Now, a falling weight (whether it be an ounce bullet or a ton) would drop 2½ feet in about ·4 sec., or 100 times as long as the shot takes to move up the barrel; the falling weight acquires 12½ feet velocity, and the shot 1250 feet, in moving the same distance. This multiple of 100 happens also to fall in very conveniently with other parts of the calculation. To give to 1⅛oz. of shot 100 times the velocity attainable in a drop lasting ·4 sec., would require a pressure equal to 100 times the weight of the shot to be kept up for an equal period of time. Now, 100 times 1⅛oz. amount to 7lb.; and a pressure of 7lb. continued for ·4 sec. would give the 1250 feet muzzle velocity, or a mean speed of 625 feet. But in ·4 sec., at that mean speed, the shot would move 250 feet, and the barrel of your gun is only 2½ feet long. Therefore, to compensate for this difference between 250 and 2½ feet, you must lessen the time to a corresponding extent, *i.e.*, reduce it to its 100th part, or ·004 sec.; and, in order to effect this, the pressure must be increased 100 times more, making it equal altogether to 10,000 times the weight of the shot. Thus we get to a pressure of 700lb. as the force requisite to impart 1250 feet velocity to 1⅛oz. of shot in a 30in. barrel; and as the area of a 12-bore is only about four-tenths (·417) of a square inch, the 700lb. applied to that area would be equal to a pressure of more than 1700lb. on the square inch.

*It may be remarked that in the foregoing observations reference is made to an assumed drop of 2½ feet, whereas the* actual fall was only 1 foot. It must be remembered, however, that if the barrel had been cut down to a foot in length, the pressure on the breech would not have been diminished; although the velocity of the shot would necessarily be less, in consequence of the force having operated for a shorter period of time. Supposing the force to be constant, the shot that attains 800 feet velocity in a 12in. barrel would have 1250 feet velocity at 30in. And a corresponding result occurs with the falling weight—it acquires 8 feet velocity in 12in., and about 12½ feet velocity in a 30in. drop; but it is a constant pressure of 7lb. for either distance, though in operation in the one case for longer time than in the other, and consequently producing higher speed.

The momentum is alike in both the above-mentioned cases. If a 7lb. weight is dropped a distance of 1 foot, the constant force of gravity imparts 8 feet velocity in ¼ second (·25 sec.) and 8 times 7lb. produce 56 units of momentum, or "force pounds" (to adopt an expression coined by Mr. Walsh when writing on this subject). If, on the other hand, 1⅛oz. of shot be propelled 1 foot in a gun-barrel under a constant pressure of 700lb., it will attain 800 feet velocity in $\frac{1}{400}$ second (·0025 sec.); and 800 times 1⅛oz. are also equal to 56 units of momentum or "force pounds." But the record on the scale of the spring balance did not represent the pounds of pressure in either case; it merely demonstrated that the pressure of a small weight acting for a comparatively long time produced a similar effect to that caused by a much higher pressure acting for a much shorter time; and an examination of the scale neither showed how high was the pressure nor how short the time.

The 700lb. pressure required to produce the velocity above stated would be *the smallest amount of force by which the work could be done*—without making any allowance whatever for friction, or for air-resistance in the barrel, both of which would add considerably to the work to be performed; nor has any allowance been made for diminished force in the gas, which would give much greater pressure at the breech than it would near the muzzle. Taking these matters into consideration, we may fairly assume that there would be a large increment on the 1700lb. pressure, and that the 2000lb. indicated by the copper disk would, after all, not be anyway over the mark. In short, there was, practically speaking, no discrepancy between the results obtained from the falling weight and those shown by the crusher-gauge.

Supposing the attempt were made to impart velocity to very heavy projectiles in the same brief space of time as with those of light weight, it will be seen what enormous force would be required to effect it. But, with increase of weight in shot, it is requisite to make use of slower-burning powder, which does not impart speed so rapidly, but keeps up the pressure for a longer period of time, and requires a longer barrel to enable it to impart the required velocity; and the lower pressure, exerted for a longer time, produces equal speed with less strain on the gun. If we apply the foregoing mode of computation to the 180lb. shot used in the artillery experiments already alluded to (page 85), we find that, owing to the longer period of time during which the pressure acts in a 9ft. gun, a comparatively smaller amount of force is required, and that, instead of its necessitating a pressure equal to 10,000 times the weight of the projectile, 3600 times would suffice. The pressure would thus amount to nearly 290 tons, which would be the constant force requisite to impart the velocity the projectile attained in the gun; but the area of the base of the shot was about 50 square inches, so that the required pressure per square inch would be rather less than 6 tons. This, it will be seen, was far below the maximum strain given by any of the four powders used in the experiment; their pressure was variable, and not a constant force, and, while the maximum pressure was greatly above 6 tons near the breech, the minimum was only about 1 ton near the muzzle. We may therefore assume that, if a constant force of 700lb. (equal to about 1700lb. per square inch) were required to perform the work done in a 12-bore gun, the maximum pressure near the breech would also be considerably higher in the shoulder gun as well as the cannon. But we could not ascertain the exact amount of variation in different sporting guns, and with different powders, unless recourse were had to a long series of experiments similar to those carried out with artillery on behalf of the Government.

### INCREASING WEIGHT OF BULLET.

Every increase in weight of projectile with the same charge of powder virtually lengthens the period of time before the shot begins to move, and thus enables greater force to be developed in the powder gases; but an increase in weight of powder (the projectile remaining as before) does not increase the velocity in anything like the same proportion. Thus, a 12-bore rifle by Holland was shot with spherical ball, with charges of 4drs., 5drs., 6drs., and 7drs. of Curtis and Harvey's No. 6 powder, and, the velocities having been ascertained by chronograph, the following table will show the per-centage of increase in initial velocity as compared with increase of powder:

| Charge of Powder. | Muzzle Velocity. |
|---|---|
| 4drs. | 1230 ft. per second. |
| 5drs., or increase of 25 per cent. | 1355 f.-s., or increase of 11⅓ per cent. |
| 6drs., or increase of 50 per cent. | 1492 f.-s., or increase of 21 per cent. |
| 7drs., or increase of 75 per cent. | 1594 f.-s., or increase of 29 per cent. |

It is not to be expected, however, that the velocity should increase in direct proportion to the increase of powder; for the amount of "energy" in the bullet is proportionate to the square of the velocity, and if the energy imparted to the bullet were increased in proportion to the amount of powder, the velocity would be only proportionate to the square-root of the respective charges. On this principle a formula was framed many years ago, by whom is not stated, but it is said to have been based on actual experiment, and was thus laid down in Cape's "Course of Mathematics," a work written for the use of Students at the East India Company's Military College, Addiscombe:—"Divide three times the weight of the powder by the weight of the shot, both in the same denomination. Extract the square root of the quotient. Multiply that root by 1600, and the product will be the velocity in feet." This formula gives the initial velocity of spherical balls with approximate correctness in many cases; but it is not strictly accurate with increasing charges and the same bullet, as will be seen by the following figures, which place in comparison the before-mentioned 12-bore velocities as ascertained by means of the chronograph, and the corresponding numbers calculated from the above formula:

| Powder. | Chronograph. | Formula. |
|---|---|---|
| 4drs. | 1230 ft. sec. | 1157 ft. sec. |
| 5drs. | 1355 „ | 1324 „ |
| 6drs. | 1492 „ | 1450 „ |
| 7drs. | 1584 „ | 1566 „ |

Here it will be observed that the velocities ascertained by the chronograph are always higher than those calculated by the formula; but the difference with the 4drs. charge is four times as great as with that of 7drs., thus showing a greater proportionate amount of energy developed in the small charge than in the large one. The reason why small charges of powder have greater proportionate energy than large ones used in the same gun, and with the same bullet, is a matter which will come into consideration further on.

When the bullet alone is increased in weight, and the powder remains stationary, the effect is the reverse of that just mentioned. The velocity is decreased, as might be anticipated, but not in a proportionate degree with the difference in weight of lead; and the heavier the bullet, the greater is the amount of energy imparted. The following figures will show the difference in velocity and energy of bullets of 280grs. and 365grs., fired with the same charge of powder (4¼drs.) from a ·450-bore rifle by Rigby:

| BULLET OF 280 GRS. | Velocity. | Energy. | BULLET OF 365 GRS. | Velocity. | Energy. |
|---|---|---|---|---|---|
| At Muzzle... | 1825 ft.-sec.... | 2082 ft.-lb. | At Muzzle... | 1700 ft.-sec.... | 2355 ft.-lb. |
| ,, 50 yds.. | 1640 ,, | ... 1681 ,, | ,, 50 yds.. | 1564 ,, | ... 1993 ,, |
| ,, 100 ,, . | 1470 ,, | ... 1350 ,, | ,, 100 ,, . | 1436 ,, | ... 1680 ,, |
| ,, 150 ,, . | 1316 ,, | ... 1082 ,, | ,, 150 ,, . | 1320 ,, | ... 1420 ,, |
| ,, 200 ,, . | 1186 ,, | ... 879 ,, | ,, 200 ,, . | 1218 ,, | ... 1209 ,, |
| ,, 300 ,, . | 1011 ,, | ... 639 ,, | ,, 300 ,, . | 1059 ,, | ... 914 ,, |

Thus, the charge of powder being the same, but the weight of lead raised from 280 to 365 grains (an increase of 30 per cent.) the muzzle velocity fell off barely 8 per cent. Yet, notwithstanding that the heavy bullet had least velocity, it had most "energy," for, under the influence of the increased resistance, the powder had imparted 13 per cent. more working-power. If the force of the powder were a constant quantity, the energy of the two bullets would be alike; but, in order for them to be equal in energy, the muzzle velocity of the lighter bullet would have to be 1940 instead of only 1825 feet per second; and even then such would only be its energy at the muzzle of the rifle.

After the projectiles have left the barrel, the greater power resulting from increased weight is more fully demonstrated. At 150 yards the above heavy bullet has the superiority even in point of speed, while its energy is now about 30 per cent. higher; and the greater comparative loss of velocity and energy by the light bullet becomes more and more marked as the distance increases.

Some examples of a similar character with Holland rifles of larger bore may also be worth quoting.

| | Velocity. | Energy. |
|---|---|---|
| ·500-bore, with 381grs. bullet and 4drs....... | 1666 ft.-sec. ... | 2364 ft.-lb., or 591 per dram. |
| ·500-bore, with 381grs. bullet and 5drs....... | 1749 ft.-sec. ... | 2605 ft.-lb., or 521 per dram. |

Increase of powder, 25 per cent.; increase of velocity, 5 per cent.; increase of energy, 10 per cent.; but, dram for dram, about 12 per cent. less work was done by the heavier charge.

| | Velocity. | Energy. |
|---|---|---|
| ·577-bore, with 502grs. bullet and 5drs....... | 1616 ft.-sec. ... | 2926 ft.-lb., or 585 per dram. |
| ·577-bore, with 502grs. bullet and 6drs....... | 1739 ft.-sec. ... | 3389 ft.-lb., or 565 per dram. |

The powder was increased by 20 per cent.; but the velocity was only increased 8 per cent., and the energy 16 per cent. by the larger charge of powder; and, taking dram for dram, nearly 4 per cent. less work was done by the larger charge.

On the other hand, the same charge of powder (6drs.) was used with ·577-bore bullets of three different weights, viz., 459 (hollow), 502, and 648grs. with the following results:

| | Velocity. | Energy. |
|---|---|---|
| 6drs. with 459grs. (hollow) | 1723 ft.-sec. ... | 3038 ft.-lb., or 506 per dram. |
| 6drs. with 502grs. (solid)... | 1739 ft.-sec. ... | 3389 ft.-lb., or 565 per dram. |
| 6drs. with 648grs. (solid)... | 1603 ft.-sec. ... | 3716 ft.-lb., or 619 per dram. |

The heaviest bullet showed 25 per cent. more energy than the lightest bullet, and 10 per cent. more than that of medium weight, though the powder was alike with each.

It appears to be clear, too, that if additional resistance is offered to the powder-gases by the cartridge-cases being very greatly turned over when the shells are made of paper, or very tightly crimped in when they are made of brass, the shot does not start so quickly, and a much higher degree of force is developed in the powder, with a corresponding strain upon the breech. Moreover, in all these matters that produce increased energy on the part of the powder, there is the fact to be considered that they also affect the recoil, and are likely to produce an amount of muzzle-disturbance that may considerably affect the accuracy of aim.

### WEIGHTS OF POWDER AND BALLS.

It may perhaps be of service to insert here a comparative list of drams and ounces, with the corresponding number of grains, as it frequently happens that weights of powder and shot are given with different nomenclatures, and it is not easy under such circumstances to estimate the proportion between the one and the other, seeing that neither the dram nor the ounce consists of even grains. Occasionally, too, people are confused by the difference between the avoirdupois and the apothecaries' dram;[*] so it may be as well to say that the latter is not used for weighing gunpowder, and is more than double the weight of the former. The avoirdupois dram, which is the one always used, is the $\frac{1}{256}$th part of a pound, or the $\frac{1}{16}$th of an ounce; consequently the dram is a small fraction over 27¼ grains (27·34375). It may be useful, too, to foreign readers to say that a "gramme" is equal to about 15½ grains (15·432); and that 1·77185 grammes equal a dram. It should be understood, however, that the miscalled "drams" of Schultze or E.C. powder are not drams at all. Like the pound, the dram is a weight, not a measure; and although a measure may be made to hold a dram or a pound of one substance, it will not hold an equal weight of all others. A 1lb. tin made for black gunpowder will only contain about half a pound of Schultze or E.C., for these explosives are only half as heavy as black powder. Yet many people make use of a measure intended for 3drs. of black powder, and on filling it with one of the nitro-compounds, say that they shoot with 3drs. of Schultze or E.C., whereas in reality they are only using about 1½drs.

Comparison of bullets may also be facilitated in some cases if the weight of spherical balls is appended; and they are therefore given in a third column.

| POWDER WEIGHTS. | | SHOT WEIGHTS. | | WEIGHT OF SPHERICAL BALLS. | |
|---|---|---|---|---|---|
| Drams. | Grains. | Ounces. | Grains. | Bore and Diameter. | Grains. |
| 0¼ | 7 | 0⅛ | 55 | 4-bore (1·052in.) | 1750 |
| 0½ | 14 | 0¼ | 109 | 6-bore (·919in.) | 1166 |
| 0¾ | 20½ | 0⅜ | 164 | 8-bore (·835in.) | 875 |
| 1 | 27⅓ | 0½ | 219 | 10-bore (·775in.) | 700 |
| 2 | 55 | 0⅝ | 273 | 11-bore (·751in.) | 636 |
| 3 | 82 | 0¾ | 328 | 12-bore (·729in.) | 583 |
| 4 | 109 | 0⅞ | 383 | 14-bore (·693in.) | 500 |
| 5 | 137 | 1 | 437½ | 16-bore (·662in.) | 437½ |
| 6 | 164 | 1⅛ | 492 | 18-bore (·637in.) | 388 |
| 7 | 191 | 1¼ | 547 | 20-bore (·615in.) | 350 |
| 8 | 219 | 1⅜ | 602 | 24-bore (·579in.) | 292 |
| 9 | 246 | 1½ | 656 | 28-bore (·550in.) | 250 |
| 10 | 273 | 1¾ | 766 | 30-bore (·537in.) | 233 |
| 11 | 301 | 2 | 875 | 32-bore (·526in.) | 219 |
| 12 | 328 | 4 | 1750 | 36-bore (·506in.) | 194 |
| 13 | 355 | 6 | 2625 | 40-bore (·488in.) | 175 |
| 14 | 383 | 8 | 3500 | 44-bore (·473in.) | 159 |
| 15 | 410 | 12 | 5250 | 48-bore (·459in.) | 146 |
| 16, or 1oz. | 437½ | 16, or 1lb. | 7000 | 50-bore (·453in.) | 140 |

By comparing the figures relative to the 4-bore and 32-bore, it will be seen that the latter is one half the diameter and one-eighth the weight of the former; the 4-bore bullet weighing ¼lb., and the 32-bore $\frac{1}{32}$lb. or half an ounce. In like manner may be found the weight and diameter of other spherical balls, as the 40-bore will enable us to ascertain that the 5-bore would be ·976in. diameter and weigh 1400grs.; and from the 10-bore we may find that the 80-bore ball would weigh 87 grains, and be ·387in. diameter. Of course this pre-supposes that the bullets are of lead throughout, and the bore of the gun is accurate, as in some cases hardened alloys are used instead of pure lead, and in others the bore is not strictly what it is represented to be.

## Work done by the Powder.

There are several ways in which the amount of work obtainable from the consumption of powder may be regarded. Some persons are anxious to obtain an exceedingly high velocity, regardless of the quantity of powder they may consume; others may look at the comparative amount of work obtained from a given charge of powder, and think they get a better return by the use of a larger weight of lead with less proportion of powder.

It appears to be beyond question that the more you increase the quantity of powder in a gun, with the same projectile, the less proportionate return you get for it in the way of work done, although you may make some addition to the muzzle velocity; and, on the other hand, the more you add to the weight of the projectile, the greater the amount of work you obtain, although there may be some loss of muzzle velocity. A few remarks on this point have already been made; but here will be found grouped together a number of records of experiments with rifles where the velocities of the bullets have been ascertained by chronograph. The details from which these particulars are collected together, have for the most part appeared in the *Field* during the last three or four years; but it has not been thought necessary to recapitulate all the circumstances connected with them, nor to give the names of the makers of the respective weapons. The purpose here is not to draw comparisons between the rifles of different makers, or to show that one gave a higher velocity or did a greater amount of work than another, but rather to point out that the same principles apply to the whole of them, although there may be certain differences of detail. In order, however, to identify the different weapons, and so make references from one to another, a distinctive letter has been applied to each;

and where the same rifle has been used several times in succession, with differences in weight of powder or lead, the same letters are repeated with a suffix, as "G A," "G B," &c. The first tables, besides giving the length of barrel and charge, will show the proportion of powder to lead, the muzzle velocity obtained, and the consequent "energy," or amount of work, produced by each dram of powder. This energy, be it observed, is the amount that exists when the projectile quits the rifle; and at the end of 100 or 150 yards the heavy bullets will retain a much larger proportion than the light ones.

VELOCITY AND ENERGY OF EXPRESS RIFLES.

| Rifle. | Barrel. | Charge of Powder. | * Weight of Bullet. | Proportion of Powder to Lead. | Muzzle Velocity. | Energy. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total. | per drm. |
| | ·400 BORE. | | | | ft. per sec. | ft.-lb. | ft.-lb. |
| A | 26in. | 3drs. | 209grs. | 1 to 2·55 | 1874 | 1628 | 543 |
| | ·450 BORE. | | | | | | |
| B | 26in. | 5½drs. | 274grs. | 1 to 1·82 | 2000 | 2431 | 442 |
| C | 28in. | 4drs. | 275grs. | 1 to 2·50 | 1901 | 2218 | 554 |
| D A | 26in. | 4¼drs. | 280grs. | 1 to 2·41 | 1825 | 2082 | 490 |
| D B | same. | same. | 365 ,, | 1 to 3·14 | 1695 | 2340 | 550 |
| E | 26in. | 4drs. | 322grs. | 1 to 2·93 | 1776 | 2254 | 564 |
| F | 33 3/16 ,, | 3⅛drs. | 480grs. | 1 to 5·64 | 1315 | 1841 | 595 |
| | ·500 BORE. | | | | | | |
| G A | 26in. | 4drs. | 381½grs. | 1 to 3·49 | 1666 | 2364 | 591 |
| G B | same. | 5 ,, | same. | 1 to 2·85 | 1750 | 2605 | 521 |
| G C | same. | 4¼ ,, | *339 ,, | 1 to 2·92 | 1699 | 2184 | 514 |
| H | 28in. | 5drs. | 342grs. | 1 to 2·40 | 1946 | 2872 | 574 |
| I | 28in. | 5drs. | 444grs. | 1 to 3·22 | 1784 | 3154 | 631 |
| | ·577 BORE. | | | | | | |
| J A | 26in. | 5drs. | 502grs. | 1 to 3·67 | 1616 | 2926 | 585 |
| J B | same. | 6 ,, | same. | 1 to 3·06 | 1739 | 3389 | 565 |
| J C | same. | same. | *458½ ,, | 1 to 2·80 | 1723 | 3038 | 506 |
| J D | same. | same. | †287¼ ,, | 1 to 1·14 | ‡1900 | 2315 | 386 |
| K | 26in. | 6drs. | 591grs. | 1 to 3·60 | 1663 | 3648 | 608 |
| L | 28in. | 6drs. | 648grs. | 1 to 3·95 | 1603 | 3716 | 619 |
| M | 28in. | 7drs. | 710grs. | 1 to 3·72 | 1730 | 4743 | 678 |

* Hollow bullets. † Spherical. ‡ Estimated velocity.

It will be observed, from the above figures relative to Express rifles, that where the same charge of powder is used, but the weight of the bullet is increased, there is nearly always a greater development of energy, whether the same rifle is used or one of different bore. For facility of reference, let us group together those where the charges of powder are equal but the bullets vary in weight, and then compare the energy given by them respectively.

| 4 DRAMS. | | Ft.-lb. | 4¼ DRAMS. | | Ft.-lb. |
|---|---|---|---|---|---|
| (C) | 275 grs. | 2218 | (D A) | 280grs. | 2082 |
| (E) | 322 grs. | 2254 | (G C) | *339grs. | 2184 |
| (G A) | 381½grs. | 2364 | (D B) | 365grs. | 2340 |
| **5 DRAMS.** | | **Ft.-lb.** | **6 DRAMS.** | | **Ft.-lb.** |
| (G B) | 381½grs. | 2605 | (J C) | *458½grs. | 3038 |
| (H) | 342 grs. | 2872 | (J B) | 502 grs. | 3389 |
| (I) | 444 grs. | 3154 | (K) | 591 grs. | 3648 |
| (J A) | 502 grs. | 2926 | (L) | 648 grs. | 3716 |

Except in one instance, the number of foot-pounds of work increases with the increased weight of the bullet. The exception occurs with the 502gr. bullet used with 5drs. of powder (J A), which gives a lower result than the 444gr. (I) with the same quantity of powder; but the latter was a rather heavy bullet of ·500 bore, and the former a rather light bullet of ·577, and the smaller-bored rifle was 2in. longer than the other.

There are but two instances in which hollow bullets were used, and these are marked with an asterisk (*). In that fired with 6drs. of powder (J C) a much lower result is shown than was obtained with the solid bullet (J B) shot with the same rifle. In the other instance, the hollow bullet (G C) was of ·500 bore and heavier than the ·450 solid bullet used with the same charge of powder. Here the higher weight gave the best result, as usual; nevertheless, that result was inferior to what was obtained with a solid bullet (E) which had a similar proportion of powder to lead, although the charge was but 4drs. It is to be regretted that there is not more available evidence about hollow bullets. We must be cautious not to draw too strong conclusions from so small a number of examples; but, as far as these go, it would appear not only that hollow bullets show a less amount of energy than solid bullets of equal size and consequently greater weight, but that they also give lower results than solid bullets of the same weight. And such seems to be only what we ought to expect; because hollow bullets must be longer than solid bullets of equal weight, and therefore would take greater hold on the rifling; and the increased amount of friction of the elongated hollow projectile would be likely to lessen its muzzle velocity, as compared with that of the shorter solid bullet. Nevertheless, we must not assume that the case is proved, for the velocities of the solid and the hollow bullets were taken on different days, and there may have been sufficient change in atmospheric conditions to account for the result if all the facts were known.

VELOCITY AND ENERGY OF LARGE-BORES.

| Rifle. | Barrel. | Charge of Powder. | Weight of Bullet. | Proportion of Powder to Lead. | Muzzle Velocity. | Energy. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total. | per drm. |
| | 12 BORE. | | | | ft. per sec. | ft.-lb. | ft.-lb. |
| N A | 26in. | 4drs. | 599¼grs. | 1 to 5·12 | 1230 | 2024 | 506 |
| N B | same | 5 ,, | same | 1 to 4·09 | 1355 | 2456 | 491 |
| N C | same | 6 ,, | same | 1 to 3·41 | 1492 | 2978 | 496 |
| N D | same | 7 ,, | same | 1 to 2·90 | 1584 | 3356 | 479 |
| | 10 BORE. | | | | | | |
| O | 26in. | 8drs. | 689¼grs. | 1 to 3·15 | 1557 | 3700 | 463 |
| P | *28in. | same | same | same. | 1567 | 3778 | 472 |
| Q | *25¾in. | 5drs. | 698grs. | 1 to 5·11 | 1316 | 2681 | 536 |
| | 8 BORE. | | | | | | |
| R A | 24in. | 9drs. | 875grs. | 1 to 3·56 | 1479 | 4272 | 475 |
| R B | same | 10 ,, | same | 1 to 3·20 | 1541 | 4638 | 464 |
| R C | same | §10drs. | same | same. | 1346 | 3539 | 354 |
| S A | 26in. | 10drs. | 862grs. | 1 to 3·15 | 1654 | 5232 | 523 |
| S B | same | same | †1257 ,, | 1 to 4·59 | 1500 | 6273 | 627 |
| | 4 BORE. | | | | | | |
| T | 24in. | 14drs. | 1257½grs. | 1 to 3·28 | 1581 | 7016 | 501 |
| U A | 25¼in. | ‡12drs. | 1250grs. | 1 to 3·81 | 1460 | 5912 | 493 |
| U B | same | same | †1882 ,, | 1 to 5·73 | 1330 | 7387 | 616 |

* Smooth bores. † Conical bullets. ‡ No. 7 grain powder. § No. 8 grain.

Spherical balls do not afford the same opportunities for comparison as elongated projectiles, because bullets of the same bore must be pretty nearly of the same weight, as the differences would mainly arise from the specific gravity of the metal, which in some cases may be of lead and in others consist of an alloy of lead with tin or some other metal. In two cases, however, in the foregoing table, viz., in the 4-bores and 8-bores, are instances of the same rifle being shot with conical as well as spherical bullets. The difference in energy of the two kinds of bullets, with equal charges of powder, is remarkable.

Comparing the figures, we find that where (as with rifles N and R), different charges of powder are used with bullets of the same size, the highest charges give comparatively the lowest results. There is a slight divergency between N B and N C, but it is so small as to be unimportant. Where the same charge of powder is used for spherical balls of different size (as N B and Q), the heaviest shows the greatest energy. S A gives a higher result than R B, although the bullet is a trifle lighter; but rifle S is two inches longer than rifle R, and so is enabled to do more work with the same charge of powder. It does not necessarily follow that the powder is unburnt in the short barrel. All may be consumed; but the nearer it is burnt to the muzzle, the less amount of work is got out of it. We therefore usually find that the small-grain powders, which are burnt almost before the projectile is set in motion, produce the greatest amount of energy, although this advantage may be counterbalanced by serious disadvantages, not the least of which is the great strain put upon the barrel. On the other hand, instances do occur in which the powder is not all burnt; and such was possibly the case with R C. The same quantity of powder (10drs.) was used as with R B; but the latter was C. & H. No. 6, and the former C. & H. No. 8. The barrel was only 24in. long, and the coarse-grained No. 8 gave but 354 ft.-lb. per dram, as against 464 ft.-lb. with No. 6. In the 4-bores there is a somewhat similar instance, but less in degree. U A, with longer barrel than T, and smaller charge of powder, should give a greater amount of energy per dram; but T used No. 6 grain powder, whereas that of U A was No. 7. The strain was less with the latter, no doubt; but, being a slower-burning powder, it did a less amount of work, even if it were all burnt. In all cases, except those just mentioned, it is believed that the powder used was No. 6.

Attention has already been called to the remarkable development of energy with the conical bullets S B and U B, as compared with the spherical balls S A and U A; but it may be remarked, as another illustration of what has been said before, that with neither conical nor spherical bullet did rifle U give so high a result per dram as S. Looking at the charges and the bores, the reverse might be expected; but U was shot with No. 7 and S with No. 6.

One other matter may perhaps be worth mention, and that is with respect to the difference of result, small though it be, between O and P. These, it will be seen, were shot with exactly the same charge and bullet, but the former was a rifle and the latter a smooth-bore. The smooth-bore gave a few feet higher velocity; but it must not necessarily be assumed that this was due solely to the difference of friction in the two barrels. The smooth-bore was two inches longer than the rifle, and thus would have an advantage; and it is possible that, if they had been of equal length, the greater initial resistance in the rifled barrel would develop in the powder an additional amount of force that might more than compensate for the loss by friction. At all events, the subject is one on which it would be interesting to have additional evidence.

## EFFECT OF LENGTH OF BARREL ON THE WORK DONE BY POWDER.

Several brief allusions have already been made to the difference of length of barrel and its influence on the amount of work done by the powder. The information afforded by the experiments summarized in the preceding tables may also be turned to account in illustration of the effect produced by barrels of *different length in varying the amount* of work done by equal charges of powder in guns of the same calibre. In Messrs. Noble and Abel's papers in the "Philosophical Transactions," the subject is elaborately gone into as regards artillery; and by utilizing the results of their labours, and adapting great things to small, we possibly may extract from the before-mentioned experiments with sporting rifles something serviceable as well as interesting.

It would occupy too much space here to give the full details leading up to Messrs. Noble and Abel's conclusions; but it may be stated briefly that they are based on the fact that, if the powder be turned into gas before the projectile has moved from its position, the gas will expand a certain number of times before the shot leaves the muzzle—the number of volumes of expansion depending upon the proportion of space occupied by the powder-charge as compared with the total amount of space in the barrel. They have accordingly prepared a table which sets forth the number of foot-tons of work which each pound of powder is capable of producing according to the volumes of expansion that occur in the gun. Of course it is necessary to know the diameter and length of the bore, in order to ascertain the amount of space contained therein; and it is also necessary to know the amount of that space which is occupied by the powder.

Pounds of powder and foot-tons of energy are far too grand in scale to serve as units for purposes of calculation in what concerns sporting rifles. Accordingly, it has been found necessary to turn them into drams of powder and foot-pounds of energy. With this amount of alteration, the following short table will afford some notion of the longer table contained in the "Philosophical Transactions," except that it omits the fractional parts of volumes of expansion and the density of products of combustion.

| Number of Volumes of Expansion. | Total work that one dram of gunpowder is capable of performing. | Number of Volumes of Expansion. | Total work that one dram of gunpowder is capable of performing. |
|---|---|---|---|
| 1 | ...... | 16 | 1174 foot-pounds. |
| 2 | 492 foot-pounds. | 17 | 1192 ,, |
| 3 | 607 ,, | 18 | 1209 ,, |
| 4 | 718 ,, | 19 | 1225 ,, |
| 5 | 800 ,, | 20 | 1239 ,, |
| 6 | 863 ,, | 21 | 1253 ,, |
| 7 | 915 ,, | 22 | 1267 ,, |
| 8 | 959 ,, | 23 | 1280 ,, |
| 9 | 997 ,, | 24 | 1292 ,, |
| 10 | 1030 ,, | 25 | 1303 ,, |
| 11 | 1060 ,, | 26 | 1315 ,, |
| 12 | 1087 ,, | 27 | 1326 ,, |
| 13 | 1112 ,, | 28 | 1336 ,, |
| 14 | 1134 ,, | 29 | 1345 ,, |
| 15 | 1155 ,, | 30 | 1354 ,, |

This table of the calculated maximum amount of work which gunpowder is capable of performing, is based on experimental results obtained during the investigations previously alluded to. The powder-pressure corresponding to a gravimetric density of unity is taken at 6554 atmospheres, equal to 43 tons per square inch, which is the corrected result for *perfectly dry* powder of Waltham Abbey manufacture, the explosive force thus being higher than when it contains moisture. This powder differs very little in composition from ordinary sporting (black) gunpowders; and the same table might be applied to mining or other powders, if taken in connection with a suitable "factor of effect" applicable to the special powder. If the powder is of less gravimetric density than unity—*i.e.*, if a measure of the powder weighs less than the same measure of water—strict accuracy would require an allowance to be made corresponding to the difference of density. Some sporting powders (especially when pressed down in a loaded cartridge) are of rather higher density than 1, but others are somewhat below; and it is scarcely necessary to complicate matters here by attempting to distinguish between them.

It will be observed, in the first line of the table, that no figures occur opposite to 1 volume of expansion; the reason being that nothing has been done. When the powder is shut up and fired, and the gas occupies only the same amount of space as the unfired powder, no work has been effected; when the force of the gas enlarges the space occupied, work has been done, but the amount would vary according to the resistance that has been overcome. The maximum amount of work which could be done by one dram of powder, in doubling the space occupied, would be 492 ft.-lb.; the maximum in three expansions would be 607 ft.-lb., and so on. Every additional expansion increases the amount of work done, but the rate of increase diminishes continuously, as the tension of the gas decreases. Thus, if one gunbarrel is of such a length that 3drs. of powder occupy $\frac{1}{10}$th of the bore, and another is of such length that 3drs. occupy only $\frac{1}{12}$th of the bore, the latter would have 12 expansions to 10 of the former. The total capacity for work in the one case would therefore be 3 (drs.) multiplied by 1030 ft.-lb., and in the other it would be 3 multiplied by 1087 ft.-lb.; consequently the same charge of powder would, in the one barrel, be able to do 151 ft.-lb. more work than it could do in the other.

Again, supposing that the barrel which allowed 12 volumes of expansion with 3drs. had its charge of powder increased to 4drs., there would be only room for 9 volumes of expansion; and its total capacity for work would be 4 times 997 ft.-lb. instead of 3 times 1087 ft.-lb. Thus, the powder-charge would be increased 33 per cent., while the maximum amount of work it could perform would be raised only 22 per cent. But the theoretical maximum never is attained, as will be shown farther on.

In order to work out any such estimations, it is necessary, of course, that the capacity of the barrel should be known, and likewise the space that the charge of powder would occupy therein. The areas of the principal Express and large-bore sporting rifles are as follows :

| EXPRESS RIFLES. | | LARGE BORES. | |
|---|---|---|---|
| ·400-bore | ·126 sq. inch. | 12-bore | ·417 sq. inch. |
| ·450 „ | ·159 „ | 10 „ | ·472 „ |
| ·500 „ | ·196 „ | 8 „ | ·548 „ |
| ·577 „ | ·261 „ | 4 „ | ·869 „ |

If, then, we have a gun of either of these bores, and a given number of inches in length, we find its cubic capacity by taking the fraction of a square inch which represents the area of the bore, and multiplying it by the number of inches in length of the barrel. To ascertain the number of volumes of expansion, we must know the amount of space occupied by the powder. A dram of powder of the gravimetric density of unity would occupy ·108 cubic inch of space; and if this be multiplied by the number of drams in the charge, and the product used as divisor of the cubic capacity of the barrel, the quotient will be the number of expansions in the barrel.

The following tables will show the result as applied to the rifles already alluded to ; the number of volumes of expansion of each rifle with the different charges being given, together with the calculated maximum energy or working-power. The energy is shown in two ways, viz., the amount per dram, and the total amount of the whole charge: the one will demonstrate the relative decrease of force per dram when increasing charges are fired from the same barrel, and the other will furnish means of comparison between the theoretical maximum calculated and the total effect obtained. The latter has already been given in the previous tables (pp. 101 and 104); but in order to afford a clearer perception of the difference of result, the percentage realised is stated in the last column of the present tables. As previously intimated, the theoretical maximum never is reached in practice, and the percentage that is obtained varies considerably, according to circumstances. In heavy ordnance, with very weighty projectiles, 90 per cent. or more may be realised; but with small artillery the percentage drops to 50 per cent. or less. A somewhat similar result is found to occur with sporting rifles. The larger the bore the higher are the results usually obtained when the weight of powder and projectile increase proportionately with the bore; and a larger percentage of the theoretical maximum from the same charge of powder results from an increased weight of bullet in the same barrel; while the substitution of a spherical ball for an elongated bullet produces a considerable reduction per cent.

WORK DONE BY EXPRESS RIFLES.

| Rifle. | Barrel. | Charge of Powder. | Weight of Bullet. | Volumes of Expansion of Gas. | Energy of Powder burnt. | | |
|---|---|---|---|---|---|---|---|
| | | | | | Calculated Maximum. | | Percentage realised. |
| | | | | | Whole Charge. | Each Dram. | |
| | ·400 BORE. | | | | Ft.-lb. | Ft.-lb. | |
| A | 26in. | 3drs. | 209grs. | 10·06 | 3092 | 1031 | 52·6 |
| | ·450 BORE. | | | | | | |
| B | 26in. | 5½drs. | 274grs. | 6·96 | 5008 | 911 | 48·5 |
| C | 28in. | 4drs. | 275grs. | 10·31 | 4159 | 1040 | 53·3 |
| D A | 26in. | 4¼drs. | 280grs. | 9·01 | 4237 | 997 | 49·1 |
| D B | same | same | 365 ,, | same | same | same | 55·2 |
| E | 26in. | 4drs. | 322grs. | 9·57 | 4061 | 1015 | 55·5 |
| F | 33$\frac{3}{16}$in. | 3⅛drs. | 480grs. | 15·71 | 3637 | 1170 | 50·6 |
| | ·500 BORE. | | | | | | |
| G A | 26in. | 4drs. | 381½grs. | 11·82 | 4338 | 1085 | 54·5 |
| G B | same | 5 ,, | same | 9·45 | 5063 | 1013 | 51·5 |
| G C | same | 4¼ ,, | *339grs. | 11·12 | 4521 | 1064 | 48·3 |
| H | 28in. | 5drs. | 342grs. | 10·18 | 5328 | 1066 | 53·9 |
| I | 28in. | 5drs. | 444grs. | 10·18 | 5328 | 1066 | 59·1 |
| | ·577 BORE. | | | | | | |
| J A | 26in. | 5drs. | 502grs. | 12·59 | 5515 | 1103 | 53·1 |
| J B | same | 6 ,, | same | 10·49 | 6270 | 1045 | 54·0 |
| J C | same | same | *458½grs. | same | same | same | 48·4 |
| J D | same | same | †287¼ ,, | same | same | same | 36·9 |
| K | 26in. | 6drs. | 591grs. | 10·49 | 6270 | 1045 | 58·2 |
| L | 28in. | 6drs. | 648grs. | 11·30 | 6409 | 1068 | 58·0 |
| M | 28in. | 7drs. | 710grs. | 9·68 | 7142 | 1020 | 66·4 |

* Hollow bullets. † Spherical.

WORK DONE BY LARGE-BORES.

| Rifle | Barrel. | Charge of Powder. | Weight of Bullet. | Volumes of Expansion of Gas. | Energy of Powder burnt. | | |
|---|---|---|---|---|---|---|---|
| | | | | | Calculated Maximum. | | Percentage realised. |
| | | | | | Whole Charge. | Each Dram. | |
| | 12 BORE. | | | | Ft.-lb. | Ft.-lb. | |
| N A | 26in. | 4drs. | 599¼grs. | 25·12 | 5226 | 1307 | 38·7 |
| N B | same | 5 ,, | same | 20·10 | 6204 | 1241 | 39·6 |
| N C | same | 6 ,, | same | 16·75 | 7124 | 1187 | 41·8 |
| N D | same | 7 ,, | same | 14·35 | 7889 | 1127 | 42·0 |
| | 10 BORE. | | | | | | |
| O | 26in. | 8drs. | 689¼grs. | 14·20 | 9084 | 1136 | 40·73 |
| P | ‡28in. | same | same | 15·29 | 9282 | 1160 | 40·70 |
| Q | ‡25¾in. | 5drs. | 698grs. | 22·50 | 6112 | 1222 | 43·9 |
| | 8 BORE. | | | | | | |
| R A | 24in. | 9drs. | 875grs. | 13·52 | 10,032 | 1115 | 42·6 |
| R B | same | 10 ,, | same | 12·17 | 10,912 | 1091 | 42·5 |
| R C | same | §10 ,, | same | same | same. | same | 32·4 |
| S A | 26in. | 10drs. | 862grs. | 13·18 | 11,157 | 1156 | 46·9 |
| S B | same | same | ‖1257 ,, | same | same | same | 56·2 |
| | 4 BORES. | | | | | | |
| T | 24in. | 14drs. | 1257½grs. | 13·80 | 15,812 | 1128 | 44·4 |
| U A | 25⅛in. | ¶12drs. | 1250grs. | 16·85 | 14,261 | 1118 | 41·5 |
| U B | same | same | ‖1882 ,, | same | same | same | 51·8 |

‡ Smooth-bores. ‖ Conical bullets. ¶ No. 7 grain powder. § No. 8 grain.

We here find an indication of some probable causes of various results to which brief allusion has already been made in commenting on the previous tables. Where (as with J A and J B, N A, B, C, and D, R A, B, and C) the same rifle and bullet are used, with different charges of powder, the percentage of the theoretical maximum realised generally varies but little. The previous tables have shown that there is a falling off of effect as compared with the quantity of powder used ; but the present figures show that the diminished result is a natural consequence of the altered condition of things, as the larger charge of powder has less opportunity of developing its energy. In the majority of cases, indeed, the larger charges of powder give a higher percentage than might be anticipated, except for the consideration that, with an increase of 20 per cent. of powder, there would not necessarily be a corresponding increase in frictional resistance to the bullet, or in absorption of heat by the barrel; and as a smaller proportion of the energy of the large charge would probably be lost in this way, the slight increase in percentage of effect may thus perhaps be accounted for. An exceptional result is found, however, with G A and G B, as here the smaller charge gives the higher percentage; but, although the same rifle was used, with bullets of equal weight, the velocities with the different charges of powder were not obtained on the same day; and there may have been such a change in the condition of the atmosphere as, if recorded, would account for the apparent irregularity of result. This seems to be the more likely, as other chronographic results taken on the second day also came out lower than had been anticipated.

Where (as with O and P) barrels of different length are used with similar charges, the percentages are generally about the same. In these cases O was a rifle and P a smooth-bore, fired with the same cartridges, and the smooth-bore gave a little higher velocity; but it had the longer barrel, and the percentage of the theoretical maximum, after allowing for the increased length, was almost exactly the same. In the case of the 4-bores, however, this does not hold good, for there the shorter barrel (T) gave a higher percentage than U A; but this result is doubtless due to the latter being used with powder of No. 7 grain. A still larger falling off is shown with R C, where No. 8 grain was used with the same barrel and ball as R B. Similar results have been found in the case of artillery: a higher percentage of effect is always given with the finer-grained powder, when used in the same gun and with the same projectile; but the disadvantage lies in the great additional strain on the gun that results from the more rapid explosion of the charge.

The means of comparison in the foregoing tables are not so numerous as could be wished, and the results, as here seen, are not always concordant; but, looking at the fact that the rifles were tried at different times, under atmospheric conditions which probably varied, but of which variations we have no record, and therefore cannot allow for, the results agree together quite as much as could be expected. We find, for example, that where the volumes of expansion run near together, the percentage realised follows pretty regularly the increased proportion of lead to powder. Here, for instance, are such of the Express rifles as afford means of comparison:

| | Rifle. | Volumes of Expansion. | Proportion of Powder to Lead. | Percentage of Energy realised. |
|---|---|---|---|---|
| GB | ·500 bore | 9·45 | 1 to 2·85 | 51·5 |
| E | ·450 „ | 9·57 | 1 to 2·93 | 55·5 |
| M | ·577 „ | 9·68 | 1 to 3·72 | 66·4 |
| H | ·500 „ | 10·18 | 1 to 2·40 | 53·9 |
| I | ·500 „ | 10·18 | 1 to 3·22 | 59·1 |
| JC | ·577 „ | 10·49 | 1 to 2·80 (hollow) | 48·4 |
| JB | same | same | 1 to 3·06 | 54·0 |
| K | ·577 „ | 10·49 | 1 to 3·60 | 58·2 |
| GC | ·500 „ | 11·12 | 1 to 2·92 | 48·3 |
| GA | same | 11·82 | 1 to 3·49 | 54·5 |
| L | ·577 „ | 11·30 | 1 to 3·95 | 58·0 |

The large-bores, when used with spherical ball, always give lower percentages than the Express rifles, but when elongated projectiles are fired from the same rifles, with the same charge of powder, there is a great increase in the percentage, as will be seen with the conical bullets SB and UB in the following table:

| | Rifle. | Volumes of Expansion. | Proportion of Powder to Lead. | Percentage of Energy realised. |
|---|---|---|---|---|
| RA | 8-bore | 13·52 | 1 to 3·56 | 42·6 |
| SA | 8-bore | 13·18 | 1 to 3·15 | 46·9 |
| SB | same | same | 1 to 4·59 | 56·2 |
| T | 4-bore | 13·80 | 1 to 3·28 | 44·4 |
| P | 10-bore | 15·29 | 1 to 3·15 | 40·7 |
| NC | 12-bore | 16·75 | 1 to 3·41 | 41·8 |
| UA | 4-bore | 16·85 | 1 to 3·81 | 41·5 |
| UB | same | same | 1 to 5·73 | 51·8 |

It must be recollected, with respect to these percentages, that the theoretical maximum is based on the assumption that the powder is perfectly dry; and it is well known that the amount of moisture in the powder considerably affects its explosive force. Then there is loss of heat, by conduction of the metal in the barrel; and the smaller the bore the larger the proportion of heat lost, and consequently the smaller expansion of gas and least working power. Hence we see big guns and hundredweights of powder giving a much nearer approach to the theoretical maximum than small-bores and drams. But loss of heat alone is doubtless not responsible for the whole reduction in percentage; there is friction to be overcome, and the resistance of the air in the barrel. These would both operate in small bores to a greater degree than in large-bore guns.

### EFFECT OF RESISTANCE ON VELOCITY AND STRAIN.

An endeavour has been made in previous pages to show that the energy of the powder increases with the amount of resistance offered by the bullet, and that by using heavier bullets with the same charge of powder a greater percentage of energy is realised, although there may be lower velocity with the heavier projectile.

Resistance of another character, such as arises from tightly turning over cartridge cases, and firmly fixing bullets in brass shells, is calculated to elicit a greater amount of force from the powder. So, too, the resistance resulting from the necessity of forcing the metal of the bullet into the grooves of the rifle, produces a further increase of force in the powder, as the initial movement of the projectile is retarded, and the powder has less space for the development of its gases; and the strain upon the breech, arising from this retardation, will depend upon the nature of the rifling, which is much deeper cut and sharper in twist in some than in others. What would be the relation between the extra force of propulsion developed in this way, and the effect of extra friction in lessening the velocity of the projectile, is difficult to say; but the main point in view here is to demonstrate that such development of force does arise from increased resistance; and two instances of burst guns that have come under my notice appear to be satisfactory illustrations of the fact.

One, a 12-bore, was loaded with a very small charge of Schultze (a fine-grained sample made before the company adopted its present mode of granulation); few wads were used, and the charge consequently did not nearly fill the paper case. The surplus paper was rolled up for nearly half an inch, being turned over and over by the machine till it formed a perfectly compact beading inside the mouth of the case; and yet the powder was in no way compressed, but, on the contrary, was rather loose within. A considerable amount of force would be requisite to drive the shot and wads through an obstruction such as here occurred; and, with a quick-burning powder like this, the whole would be consumed, and the gases in a high state of tension, in much less time than would be required to unroll the convolutions in the paper. Insufficient time being given for the shot to get into motion, it became a question of what was to give way first; and the question was answered by a piece of metal being driven out of the side of the barrel.

The other burst gun was a 16-bore, loaded with a larger charge of granulated Schultze powder, which, under ordinary circumstances, would scarcely be so rapid in combustion as the dust-like sample before mentioned. The charge was in a brass "Perfect" case, tightly crimped in; and the owner of the gun, after the accident, had an experiment made to ascertain the amount of force required to drive the shot and wads through the crimping. He had the base of the shell drilled out, the powder removed, and weights put on; and nearly a hundredweight had to be applied (109lb. if I remember rightly) before the charge of shot began to move. Here, then, the resistance would be about 1800 times as great as the mere weight of the shot, and (after what has been said at page 76 *et seq.*) it is not surprising that before time had elapsed to admit of motion in the shot, and thus permit of expansion in the powder-gases, the tension had become so high as to burst a not over-strong barrel.

As is usually the case, the results of experiments carried out with small arms are but confirmatory of what has been ascertained with respect to big guns ; and the experiment just mentioned runs on very nearly the same lines as one alluded to by Professor Bashforth at page 16 of his "Treatise on the Motion of Projectiles." After stating that, "when quick-burning powder was used for large guns it was most important to consider the initial motion of the shot, so as to provide for an early increase of space for the gas to occupy," he comments on the law laid down by Professor Hélie as to the rifling of guns with an increasing twist, and then proceeds as follows (the *italics* being his own):

> "It is undoubtedly right in principle to free the initial motion of the shot, as far as possible, from all needless obstructions. The increasing twist has, as we have seen, been tried in deference to this principle, only it is at present doubtful whether the advantages secured by its adoption counterbalance the practical disadvantages of its employment. But the Armstrong system of breechloading ignored all considerations of this kind, for a 'grip' in the bore was placed just in front of the seat of the shot, while the shot was covered with a thin coating of lead to take the rifling. An experiment was made at Woolwich in 1865 to determine the statical pressure required to force a 12lb. shot along the bore of an Armstrong breechloading gun. (Quarterly Proceedings of the Ordnance Select Committee, 1865, p. 23.) It was found that a pressure of from 16¼ to 20 tons was necessary to force a cold 12lb. shot through the 'grip' in front of the shot chamber, and a pressure of from 3 to 5½ tons to force it along the bore. It is plain that the shot could

not move forward before a tension of the exploding powder was sufficient to exert a pressure of 16 tons on the base of a 3-inch shot, and even after that the shot would move slowly. This would cause so *great a loss of time*, that probably the whole of the powder would be exploded before the shot had moved sensibly from its seat, and consequently the *gas would exert its greatest possible destructive force upon the gun.*"

Since 1865 considerable changes have been made both in the powder and the construction of big guns; but this principle applies to sporting rifles as well as artillery, and the increase of force with the latter is only on a larger scale than it is with small arms—the pressure being about 3000 times the weight of the projectile in the case mentioned in the above extract, and about 1800 times in that of the 16-bore which came under my notice.

Another artillery experiment shows that the retardation of initial movement in the projectile has the effect of increasing the velocity of the projectile as well as being likely to exercise a destructive force upon the gun; and in this respect it is confirmatory of the results shown by the experiments with Express rifles, viz., that the greater resistance of the heavier bullet induces greater energy in the powder; and it also proves that increased resistance, where the projectile is not heavier, likewise induces greater energy, which, under these circumstances, takes the form of enhanced velocity. In Messrs. Noble and Abel's second paper in the "Philosophical Transactions" (1880, pp. 242-3), it is stated that it had been found that with certain breech-loading guns a superior effect was attained by substituting copper rings for lead coating on the iron shot, and it had been assumed that the cause of this superiority was due to the less friction of the copper rings in the passage of the shot up the bore. Experiments were carried out to ascertain the facts; shots were fired coated with the ordinary service quantity of lead, and the results compared with those of others on which the lead had been considerably reduced, so as to diminish friction. The reduction of friction did not increase the realised amount of energy in the powder, but, on the contrary, it was slightly reduced. Rounds were then fired with shell fitted with copper rings, and there was a gain in velocity, but the pressure in the chamber of the gun was found to be raised from 16·8 tons to 18·6 tons per square inch, showing that the increased effect had not been caused by a reduction of friction, but was owing to the increased difficulty of forcing the copper bands into the grooves, and to the powder being consequently burnt earlier in the bore. The paper then proceeds as follows :

"To show the effect of a greater or less degree of retention of the shot in its chamber in as clear a light as possible, the following experiments were made. Four projectiles for a 12-centimetre B.L. gun were manufactured of precisely the same weight, and which differed from one another in the following respect only : that two of these were fitted with a rotating gas-check of such a form that a high pressure would be necessary to force the projectile into the bore ; the two others being fitted with gas-checks of a form such that a comparatively feeble pressure only would be requisite. The copper surfaces in contact with the bore were the same in each case.

Two rounds, one with each form of gas-check, were then fired with a charge of 7lb. of R.L.G. powder, every condition, except as noted, being precisely the same. The velocities with the two forms were respectively 1609 feet per second and 1512 feet per second, giving rise to 82·04 and 72·44 foot-tons per lb. of powder. The chamber pressures were respectively 15·2 and 12·0 tons per square inch.

Two further rounds were then fired with 7½lb. R.L.G., when velocities of 1644 and 1544 feet per second, or energies per lb. of 79·94 and 70·51 foot-tons were respectively obtained, the chamber pressures in this case being 16·4 and 14·1 tons per square inch.

These experiments prove in a most complete manner that, although there may be, and doubtless is, some difference in the amount of friction due to the employment of lead or copper as the driving or rotating material, that difference is perfectly insignificant when compared with the alteration in energy due to the projectile being more or less retained in its initial position, and thus permitting the powder to be consumed earlier and in a more complete manner."

The "foot-tons of energy per lb. of powder" in the above quotation are obtained from the number of expansions in the bore, and correspond with our "foot-pounds of energy per dram" in the table about Express rifles on page 110. The results shown in the quotation will become more clear if tabulated. In the first place, the connection between the chamber pressure and the muzzle velocity, with merely an increase of powder, may be shown thus:

| | Charge of Powder. | Velocity. | Chamber Pressure. |
|---|---|---|---|
| | 7lb. | 1512 ft.-sec. | 12·0 tons. |
| | 7½lb. | 1544 " | 14·1 " |
| Increase ...... | 7 per cent. | 2·1 per cent. | 17·5 per cent. |

The next will show the difference of effect with both charges when the resistance was increased:

| Resistance. | Muzzle Velocity from | | Chamber Pressure from | |
|---|---|---|---|---|
| | 7lb. powder. | 7½lb. powder. | 7lb. powder. | 7½lb. powder. |
| Small ......... | 1512 ft.-sec. | 1544 ft.-sec. | 12·0 tons | 14·1 tons. |
| Great ......... | 1609 " | 1644 " | 15·2 " | 16·4 " |
| Increase... | 6·4 per cent. | 7·1 per cent. | 26·7 p. cent. | 11·6 p.cen |

It will be observed that the increase of velocity from the greater resistance is about three times as much as that arising from the increase of powder. Also, that the lesser charge of powder with great resistance gives higher strain on the breech than the larger charge with small resistance. And, further, that although the large charge more than keeps up the percentage of increased velocity arising from greater resistance, yet the *relative* increase in chamber-pressure is much smaller than before.

Taking, too, the total amount of work done, both by increase of powder and increase of resistance, we find the percentage from the latter was again much higher than from the former.

In the next short table, the increase from the extra powder is *given at the end of the line, while that due to extra resistance* is given beneath.

| Resistance. | Total work done by | | Increase. |
|---|---|---|---|
| | 7lb. powder. | 7½lb. powder. | |
| Small | 507 foot-tons | 529 foot-tons | 4·3 per cent. |
| Great | 574 „ | 599 „ | 4·4 „ |
| Increase... | 13·2 per cent. | 13·4 per cent. | |

Returning again to small arms, we have another mode of showing the different degrees of force in different rifles. The four accompanying woodcuts represent four crusher-gauges made of lead, which were kindly furnished by Major McClintock, R.A., who had carried out experiments with them. Fig. 11 is the full-size representation of one that has not been used. Fig. 12 represents one that has been submitted to the pressure arising from the Snider-Enfield charge of 70grs. of powder with 480gr. bullet of ·577 bore; it has been shortened a trifle by the explosion, but otherwise is little altered in shape. Fig. 13 shows the greater effect produced by the Martini-Henry charge of 85grs. with a 480gr. bullet of ·450 bore, by which it has been shortened and made more rotund; and Fig. 14, which is very cheese-like in shape, represents the still greater amount of "crush" effected by a Gatling cartridge. The latter has the same powder and bullet as the Martini, but is inclosed in a stout brass case, very tightly clasping the projectile, which thus gives much more resistance to the expansion of the gases. The relative pressures on these bullets

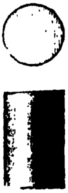
Fig. 11.

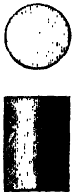
Fig. 12.

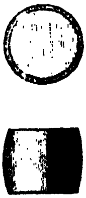
Fig. 13.

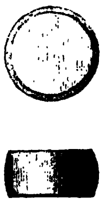
Fig. 14.

were estimated to be—Snider, from 2 to 2½ tons; Martini, 4½ to 5 tons; and Gatling, about 7 tons per square inch. The area of the ·577 being about 1⅔ that of the ·450 bore, the whole pressure given to the Snider bullet would be approaching that of the Martini, and, the bullets being equal in weight, their muzzle velocities would be not very far apart; but the "pressure per square inch" on the circumference of the bore would, in the Martini, be very much greater than in the Snider, and greater strength of barrel would be required to withstand the strain. It is not uncommon for small barrels to be made thinner than large-bores because the charge of powder is less; but, as previously pointed out, the strain does not depend alone upon the quantity of powder; and in small-bores the resistance from turning-over, &c., is sometimes even greater than with large-bores. Possibly this may explain the number of accidents that have occurred of late with 16 and 20-bore guns, the percentage of those that have been burst by E.C. and Schultze powder being apparently much larger than in the case of 12-bores.

But, returning to the crusher-gauge experiments, the most remarkable feature is the enhancement of force by the increased resistance of the Gatling cartridge-case, the bullet and powder being just the same as those of the Martini. I may add that Major McClintock considers these estimates as but approximately correct, the pressures of only a few rounds of each having been taken. These pressures, moreover, were not taken in the chamber itself, but just in front of the chamber; consequently the gas would not operate on the crusher-gauge until after the bullet had been moved, and when the pressure had possibly somewhat diminished.

It is a well-known fact that many of the most skilful rifle-shots prefer to load their own cartridges, as they thereby can insure an equality of manipulation that is not to be expected from those that are commercially loaded; and the regularity of shooting well repays them for their pains. I am convinced, from a careful inspection of the targets at the *Field* Rifle Trial at Putney, in October, 1883, that difference of care in the loading of the cartridges had a good deal to do with some of the weapons not giving better results as compared with others. On looking at chronograph records, too, it is not an uncommon thing to find successive shots in the same series vary 50 feet or more in their muzzle velocity, while in other batches a remarkable degree of uniformity is shown; and it seems by no means improbable that an important factor in such variations may be the different amount of resistance arising from the varying degrees of firmness with which the bullets are fixed into the brass shells. Some carefully carried out experiments to ascertain the facts might be advantageous in various ways, and, amongst others, in connection with the subject-matter of the ensuing section.

## EFFECT OF ATMOSPHERIC PRESSURE ON THE DEVELOPMENT OF FORCE IN POWDER.

In a previous chapter (p. 65 *et seq.*) allusion has been made to the differences in amount of bullet-drop that may arise under reduced barometrical pressures with a given muzzle velocity; and it is intimated that the effect of change of temperature, &c., would be touched on in the chapter treating on the calculation of the trajectory. There is, however, another point which deserves consideration, in connection with the subject now under discussion, viz., the effect which may be produced on the velocity of the bullet at the muzzle by the difference of resistance to its initial motion at the breech of the gun, and that is, the effect of atmospheric pressure in varying this resistance. Additional point has been given to this matter by the following letter recently addressed to Mr. Walsh:

98, New Bond-street, London, W., Feb. 6, 1884.

MY DEAR SIR,—Frequently I have had complaints from correspondents who have been shooting with Expresses in the Himalayas in India, and the Rocky Mountains in America, that their rifles shoot low. I could not understand it, knowing that the rifles were correctly sighted, and in most cases pretty sure that the ammunition was right. One of these correspondents came over on sick leave, and went to our ground, and, to his surprise, instead of the rifle shooting some 12 or 14 inches low, as he said it did, it appeared to be about right. Again, Major C. called to-day and told me much the same thing. Well, this morning I received an order for an Express from America. The writer of this order particularly mentions that the barrels must be extra long, and sighted rather high, as he is shooting some 9000 feet or more above sea-level; and he says that, at these high altitudes, elevations are very different, and he believes the powder does not all burn. Will you ask your scientific friends if there is anything in it? If there is, it may be worth mentioning in your book.

Yours faithfully,
HENRY HOLLAND.

J. H. Walsh, Esq.

Nothing is here said as to temperatures, or to length of range; and, as remarked in the previous chapter, the lowness of temperature at high altitudes tends to counteract the effect produced by the height above sea-level, while the variation in drop would greatly depend on length of range.

The observations made in a previous chapter had reference to the effect which would be produced on certain bullets supposing that they had the muzzle velocities there stated, and that the temperature was about the normal standard. The effect of reduced temperatures will come on for future consideration; and it will suffice here to say that a reduction of about 15° in temperature would compensate for a fall of an inch in the barometer. It is obvious, therefore, that the temperature would not be so low as alone to counteract the effect of the barometrical pressure being reduced by 10 inches, as in the 11,000 feet elevation assumed for the calculations previously given. The drop in the bullet alluded to in Mr. Holland's letter must therefore be due, in great measure, to some other cause, and that cause most probably is the amount of atmospheric pressure in the bore of the gun.

In an article of mine, inserted in the first volume of this work, some remarks were made (pp. 305-6) with respect to the different amounts of force given forth by gunpowder under different degrees of restraint. After stating that the force of the explosion increases with the strength of the envelope in which the powder is confined, and that the ignition of unconfined powder in the open air (under ordinary conditions of atmospheric pressure) does not show the lowest development of force, the article proceeds as follows:

> "If the explosive be fired in a rarefied atmosphere, as on a high mountain or under the exhausted receiver of an air pump, its violence decreases according as the pressure is reduced below the ordinary pressure of the atmosphere. This difference of resistance has an important influence on time-fuses; for Quartermaster Mitchell found, by some experiments carried out in India, that fuses which burnt out in 14 seconds at the sea-level, required no less than 18 seconds in the hills, at an elevation of 7300 feet; and Dr. Frankland, by means of experiments in artificially rarefied atmospheres, discovered the law of this variation, which he explained in a paper read before the Royal United Service Institution. He showed that the mere change in our daily atmospheric pressures caused an appreciable difference in result, as a fall of one inch from the ordinary barometrical standard of 30 inches would decrease the time of combustion by $\frac{1}{30}$th; so that a half-minute fuse would require about 31 seconds to burn out at 29 inch pressure, and rather more than 32 seconds at 28 inches. At 7300 feet the barometrical standard is rather under 23 inches, and the time occupied in the combustion of the fuse was increased nearly one-fourth."

This appears to bear on the effects alluded to by Mr. Holland's correspondents. We have already seen, from the experimental results with sporting rifles and big guns lately commented on, that when tho resistance to the initial motion of the shot is increased, the powder exhibits greater energy; or, to put it the other way, whenever the amount of resistance is lessened, the powder, having less work to do, does not put forth so much energy. The projectile begins to move under a lower pressure, and the powder gases never acquire so high a tension.

Let us apply this to the state of affairs depicted in Mr. Holland's letter. When the rifle is fired, motion on the part of the bullet is resisted (1) by the weight of the bullet itself, which we will assume to be one of ·450 bore, weighing 350grs.; (2) it is further resisted by crimping or swedging, which fixes the bullet in the case, as well as by the rifling, into which the metal of the projectile has to be forced—giving a combined amount of resistance which it is not easy to estimate, but which must be vastly beyond the mere weight of the bullet; and (3) the bullet has bearing on it an atmospheric pressure of about 15lb. to the square inch. The rifle being of ·450 calibre, this pressure would amount to nearly 2½lb., or about 50 times the weight of the 350gr. bullet—that is, supposing the gun were fired near the sea-level. But if it be fired at an elevation of, say, 11,000 feet, where the barometer would stand at about 20″, the atmospheric resistance would only be about 10lb. to the square inch, and thus be only about 34 times the weight of the bullet. The conditions No. 1 and No. 2 would remain as before, but No. 3 would only operate to two-thirds of its previous extent; a less amount of resistance would be offered to the expansion of the gases, and they would therefore develope less energy; with less energetic propulsion, the bullet would have a lower muzzle velocity, and tho bullet would drop more in a given distance owing to its slowness of flight.

Such is a theoretical explanation of the effect described; but no practical means, as far as I am aware, have ever been adopted to test it. And it seems scarcely possible to prove it satisfactorily without careful experiments by means of scientific instruments, such as the chronograph, taken to high altitudes, so as to ascertain the muzzle velocity of rifles with ammunition which has been proved to give certain velocities near the sea-level. An approximate estimate of the muzzle velocity might perhaps be formed by methods of calculation hereafter to be described; but they would only be approximations, and open to the charge of being erroneous. If, however, anyone would carry out a scientific inquiry into the matter, facts of considerable interest would doubtless be obtained; but, until such is done, one cannot do more than speculate as to what the results would be. Projectiles of light weight would be most affected; but otherwise the results would be likely to vary with nearly every rifle and bullet, according to the proportion which atmospheric resistance bears to other forms of resistance in the barrel.

Supposing, however, it to be proved that diminished atmospheric pressure has the effect of reducing the muzzle velocity of the bullet, there is an opening for further experiment to ascertain whether the loss of resistance might not be remedied by the sportsman at high altitudes carrying a light swedging apparatus to crimp the brass shell more firmly into the bullet.

## EFFECT OF MOISTURE ON GUNPOWDER.

The quantity of moisture in gunpowder considerably affects its rapidity of explosion and the amount of energy it imparts to the projectile. Whatever the proportion of water in the powder, it has to be turned into steam by the combustion of the other ingredients; consequently inflammation is retarded, and the heat, which would have increased the explosive force, is considerably lessened. The difference in the amount of work done by powders containing different proportions of moisture, but otherwise exactly alike, was tested by Messrs. Noble and Abel. They experimented with a series of samples of pebble powder, carefully prepared with proportions of moisture varying from 0·70 to 1·55 per cent., and the muzzle velocities of the shot, and maximum pressures in the cannon from which they were fired, were found to be as follows:

| Percentage of Moisture. | Muzzle Velocity. | Maximum Pressures. | Percentage of Moisture. | Muzzle Velocity. | Maximum Pressure. |
|---|---|---|---|---|---|
| | Ft. per sec. | Tons per sq. in. | | Ft. per sec. | Tons per sq. in. |
| 0·70 | 1545 | 22·02 | 1·15 | 1514·5 | 19·37 |
| 0·75 | 1541 | 21·70 | 1·20 | 1512 | 19·12 |
| 0·80 | 1537 | 21·38 | 1·25 | 1509·5 | 18·87 |
| 0·85 | 1533·5 | 21·07 | 1·30 | 1507 | 18·63 |
| 0·90 | 1530 | 20·77 | 1·35 | 1504·5 | 18·40 |
| 0·95 | 1526·5 | 20·47 | 1·40 | 1502 | 18·18 |
| 1·00 | 1523·5 | 20·18 | 1·45 | 1499·5 | 17·97 |
| 1·05 | 1520·5 | 19·90 | 1·50 | 1497·5 | 17·76 |
| 1·10 | 1517·5 | 19·63 | 1·55 | 1495·5 | 17·55 |

The authors of the paper add: "From this table it will be seen that by the addition of considerably less than 1 per cent. of moisture, the muzzle velocity is reduced by about 60 feet, and the maximum pressure by about 20 per cent., pointing obviously to a much more rapid combustion in the case of the drier powder."

Some examples of results obtained in experiments carried out by Capt. J. E. Greer, of the United States Ordnance Department, are also interesting.

Two kegs of fine-grain powder were taken into a room kept heated by a stove night and day. One keg was opened, and a sample therefrom was exposed in an open vessel in the room for three days, at the end of which time it was made up into cartridges. The other keg was then opened, and cartridges made up from the unexposed powder. Both samples of cartridges were tested. Those loaded with the powder which *had undergone three days' drying gave an initial velocity of 1391 feet per second; those loaded with the undried powder gave only 1340 feet per second.*

Some of the dried powder from keg No. 1 was then placed under a covered porch in the open air, and left exposed for three days, during part of which time it rained almost incessantly. Cartridges were made up from this powder; and the initial velocity, which had been 1391 ft.-sec. when the powder was dry, now fell to 1347 ft.-sec.

More samples of the same powder were exposed to the air of a heated room, for periods of three, six, and nine days respectively, after which they were made up into cartridges, and kept for four months. At the end of that time they were tested, and it was found that the powder dried for three days gave 1390 ft.-sec. velocity; that dried for six days gave 1395 ft.-sec.; and that dried for nine days gave 1407 ft.-sec. Evidently the cartridges must have been kept in a very dry place in the interim, as the powder that had undergone three day's drying gave at the end of four months virtually the same velocity as had been given when it was first dried.

A curious instance of the difference in the effect produced by the damping and re-drying of powder occurred in the course of some experiments carried out on behalf of the United States Government by Major Mordecai. One sample of powder, by reason of its high density and slow rate of combustion, gave a lower velocity than some other powders with which it was tested. The different powders were exposed to a very damp atmosphere for a long time, and subsequently re-dried. Most of them had deteriorated more or less; but this very dense sample gave better results than it had given originally. The moisture had caused the grains to swell, and when re-dried they retained their enlarged size; consequently they were more pervious, and, from their more rapid combustion, imparted higher velocity to the shot.

# CHAPTER VI.

## THE TRAJECTORY OF THE BULLET.

From what has already been said, it will be seen that the form of the trajectory-curve of the bullet is dependent on various circumstances, the most important of which are the force of gravity and the resistance of the atmosphere. As the extent of the influence of gravitation depends on the length of time it is in operation, and as increased velocity necessarily shortens the time of the bullet's flight, the speed with which it is propelled from the gun must consequently have a considerable effect upon the formation of the curve; and as the weight and shape of the projectile regulate the amount of retardation which it undergoes from air-resistance, these matters also have to be taken into consideration when we attempt to trace the bullet's course.

It has previously been pointed out (page 47) that the bullet begins to drop from the very instant that it quits the muzzle of the gun, and that, unless the muzzle were raised to some extent, the projectile would never hit the object aimed at. Every sportsman is aware that the elevation which is given to the gun—whether it be by a movable back-sight, or by a raised rib or plate, or merely by the barrel being thicker at the breech than at the muzzle—has the effect of compensating for a drop of the shot at a given distance. But it does not occur to everyone that this compensation is far from uniform throughout the line of flight, and that, in order to hit the mark at 200 yards distance, the muzzle must have four or five times as much elevation as is required for 100 yards; nor

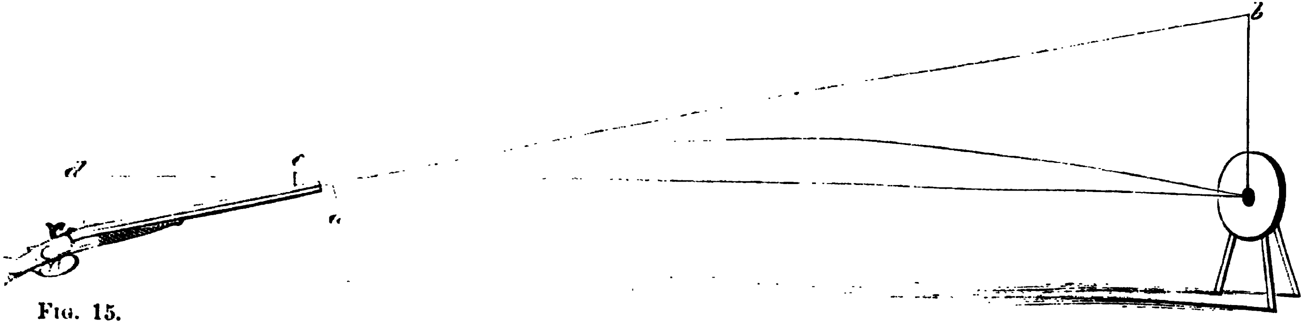

FIG. 15.

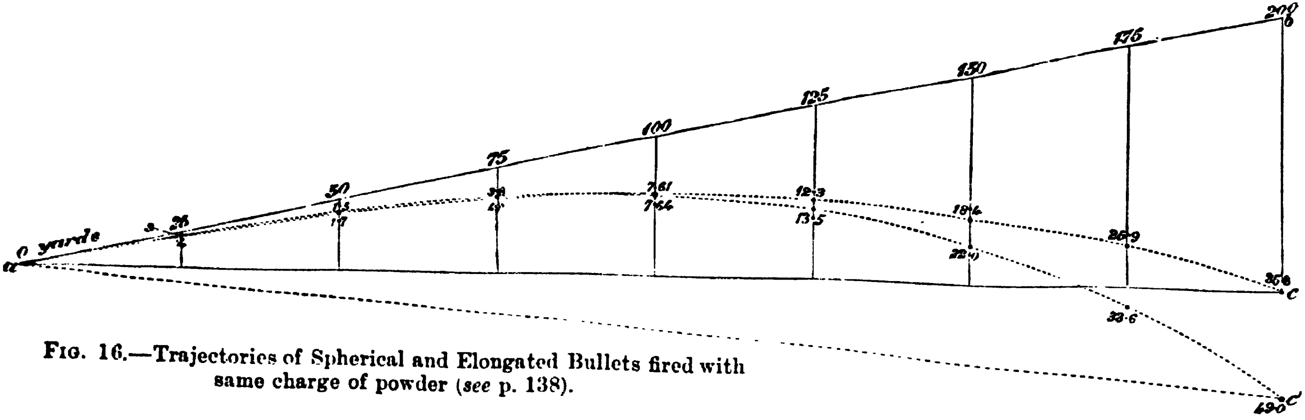

FIG. 16.—Trajectories of Spherical and Elongated Bullets fired with same charge of powder (*see* p. 138).

does it necessarily strike him, without explanation, that if he fires at an object at 100 yards, with a rifle sighted for double that distance, the bullet will hit considerably above the line of aim. That such must be the case will, however, be seen by the illustration given opposite (Fig. 15), which is drawn, however, on an exaggerated scale of elevation, as compared with length of range, in order to adapt it to the dimensions of the page. The line *a b*—a continuation of the long axis of the barrel—shows the *line of fire*, or *projection*, or *elevation*; and, were it not that the bullet is attracted to the earth by the force of gravity, the line of its flight throughout would be coincident with the line of fire, and it would strike any object placed at *b*. The line *d e*, which is the *line of aim* or *sight* or *vision*, is carried direct from the back to the front sight, and onwards to the object aimed at. But neither the line of aim nor the line of projection indicates the line of flight of the bullet, which takes a curved course between these two straight lines—apparently ascending for about one half of the range and descending for the rest of the distance, though really dropping from the line of projection from the very first.

It will be observed that the curve keeps pretty close to the line of fire in the early portion of the range, and is about midway between the two lines at the half distance, after which it falls off much more rapidly from the line of projection. As previously remarked, the effect produced by raising the muzzle of the rifle, to counteract the fall of the projectile, is not uniform throughout the bullet's flight; for the upward line in which the bullet is fired rises in height in direct proportion to the increase of distance, whereas the fall of the bullet is in proportion to the "square" of the time of flight. Hence, the compensatory elevation must necessarily be in excess at the beginning of the range, and deficient afterwards, so that the bullet will first rise and then fall, till, at the end of the

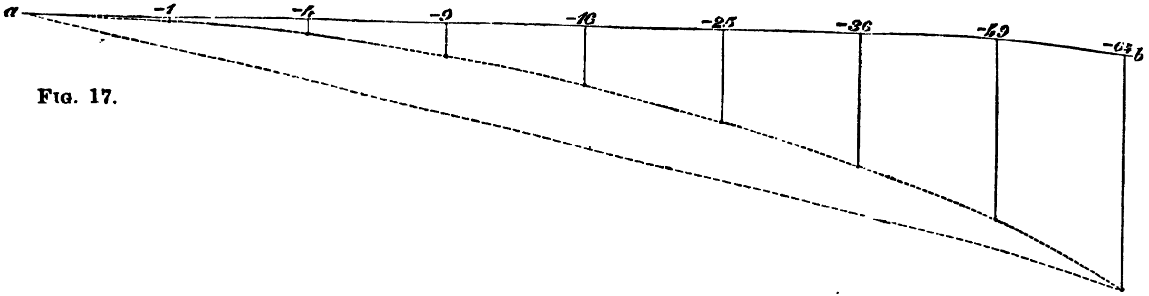
a
-1
-4
-9
-16
-25
-36
-49
-64
b

**Fig. 17.**

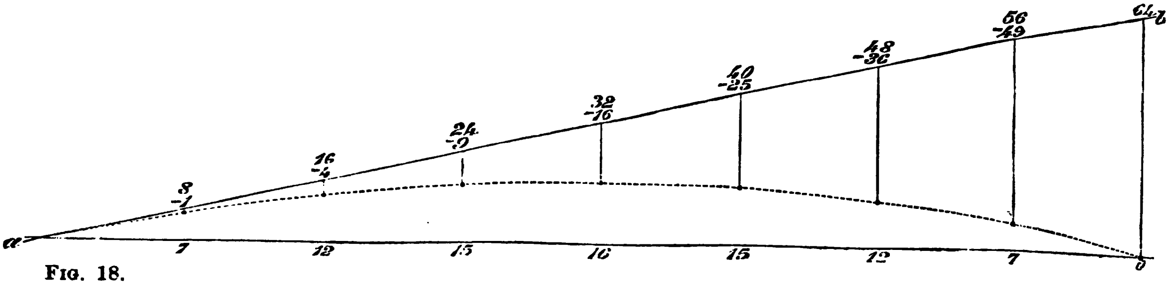
a
-1
-4
-9
-16
-25
-36
-49
b

**Fig. 18.**

distance for which the rifle has been sighted, the projectile will have come down again to a level with the line of aim.

A tolerably good representation of the effect of these counter-influences may be obtained by means of a rod from which beads are suspended by threads varying in length, as shown in the accompanying diagram (Fig. 17).

Here the rod *a b* (which is supposed to represent the line of fire or projection) is horizontal, to illustrate the case of a gun in which there is no elevation whatever to counteract the fall of the projectile; consequently, in such case the line of fire and the line of aim would be parallel, supposing the barrel to have no increase of thickness at the breech. The suspended beads mark the course of the bullet, and the length of each thread shows the amount of fall from the line of projection at that point. The rod may be taken to represent a range of any given length, and the figure 1 over the first thread may represent full inches or fractional numbers as desired; but here it will be easier to consider the first thread as one inch long, the whole range as 200 yards, and the divisions as 25 yards each.

For the sake of simplicity, and to avoid the use of fractional numbers, it will be assumed that the velocity is uniform throughout, and consequently that the equal distances represent equal times. This, of course, is not strictly correct, for, if equal times were accurately represented, the distance between the threads would gradually diminish; or, on the other hand, if the distances be taken as accurate, the length of the early threads would require to be somewhat shorter, and the others somewhat longer.

Supposing, then, that in the time taken to travel the first 25 yards of the range a bullet is drawn down one inch from the straight line, it will, in the subsequent periods of equal length, descend in accordance with the numbers given above the threads in the diagram; *i.e.*, the fall in the first period being 1in., it would be 4in. at the end of the second, increasing in the third to 9in., and so on, in accordance with the square of the number of periods, as already set forth at page 52, in the chapter on the drop of the bullet.

But, although we have seen how the bullet will fall if we hold the rifle in a perfectly horizontal position, we seldom want to use one in that way, and accordingly we lift the muzzle till the bullet starts at a greater or less angle with the horizon. Let us say that the muzzle is raised to such a point that the bullet will strike on the line of sight after traversing 200 yards. The raising of the muzzle makes no difference in the velocity of the projectile (except, as in the case of artillery, the shot ascends to very great heights, where density of the air is diminished); nor will it interfere with the action of the force of gravity; and, as the time would thus remain the same for the same distance, the amount of drop would also be unaltered. Accordingly, let us lift the rod which represents the line of projection (*a b*) until the last bead touches the line of sight (*a c*), when every intervening bead is raised above the line of sight, as shown in the other diagram (Fig. 18).

In order to compensate for the fall of 64 inches in 200 yards, the angle has to be such that the line of projection will, at the end of that range, be taken up to the point *b*, 64 inches above the line of sight. The bullet, however, rises but a small portion of that height, as the operation of the force of gravity is now shown by its obstructing the ascent of the bullet in the first half of the range, and pulling the projectile down after it has passed the middle point. At the beginning, as will be seen by the dotted curve in the diagram, the departure of the bullet from the line of projection is trifling; the drop, which is little more than a thousandth part of an inch in the first yard, needs time to accumulate, and the space of 25 yards is passed by the time the fall amounts to an inch; meanwhile the line of projection has ascended 8in. above the line of sight, as is indicated by the figures on the diagram, where the topmost numbers denote the rise of the angle, the negative numbers immediately underneath indicate the fall of the bullet, and the numbers below the line of sight give the difference between the two, or, in other words, the height of the trajectory at each point. So the counter-influences proceed, till the rapid ratio of descent by force of gravity overmasters the slower ratio of rise by the angle of elevation, and then down comes the bullet towards the level of the line of sight.

So high a trajectory as here given does not, we will suppose, meet our requirements. Let us see what will be the result of shortening the range to 150 yards. We therefore reduce the angle of elevation, and lower the rod accordingly till the sixth bead touches the line of sight. Then we find the height of the trajectory reduced to about one half of what it was before, so great has been the effect of the drop of the bullet in the latter portion of the range, where two beads will now hang under the line of sight. If we lower the rod again, there will be a further reduction in the height of the trajectory; and when the 100 yards bead touches the line, we shall find the trajectory only one-fourth as high as it was at 200 yards.

This, however, as before stated, is on the supposition that the bullet retains the same velocity; but, inasmuch as we cannot have a bullet that loses no speed, we cannot have a trajectory so flat as here alluded to. This remark, however, is not meant to refer to the curve as it strikes the eye in the diagram; for in order to represent a range of 200 yards in the space of a few inches, the vertical lines are necessarily on a larger scale, or they would be indistinguishable. Nor is it meant that, in a range of 200 yards, the trajectory must necessarily be the number of inches in height that is stated in the diagram; for the height would, of course, depend upon the speed of the bullet, and the consequent time during which the force of gravity would be in action to pull it down towards the earth. But, supposing the time of flight were such that the bullet drops 64 inches in 200 yards, the height of the trajectory must exceed 16 inches; and the extent of the excess would depend upon the form and weight of the projectile.

In Fig. 18, with an assumed equality of speed, it will be seen that the height of the imaginary trajectory at the middle point is exactly midway between the line of sight and the line of projection, and consequently that it is one-fourth the height of the total fall in the whole range; at 50 yards and 150 yards, too, the beads are equal in height. But actual trajectories never have this equality, because the first part of the distance is travelled at greater speed than the last; accordingly the bullet continues to rise somewhat beyond the middle point of the range, and the highest point of the trajectory is always more than one-fourth of the entire fall. The height varies at different points with different rifles and charges, and it will be higher with a spherical ball than with an elongated bullet that traverses the same distance in the same period of time; for the longer and heavier the bullet in proportion to its diameter, the less will it vary in speed, and the nearer will it approach in regularity to the imaginary trajectory that has been given. On the other hand, the spherical ball, in order to accomplish the same distance in the same time, must start with greater velocity, and it would consequently always be higher than the elongated bullet until the time of flight is equalised. By reason of its greater speed, it would necessarily drop less in the first part of the range; and although, after passing the turning-point, it would descend more rapidly than the long bullet, owing to a greater loss of velocity, it would not be until this loss had counteracted the previous gain that the two bullets would come to the same level—*i. e.*, supposing their line of elevation were alike originally.

The following particulars, and the diagram on page 130 (Fig. 16), will show how two bullets of the same bore, fired with the same charge of powder, vary in trajectory. The calculations were originally published in the *Field* on the occasion of a trial of Messrs. Holland's rifles in 1879.

The spherical ball and the Express bullet were both of ·577 bore, and both shot with 6 drams of powder. The long bullet (648 grs.), which was of more than double the weight of the spherical ball (287 grs.), had rather over 1600 ft.-sec. muzzle velocity, and the spherical ball had about 300ft. higher initial speed, yet, owing to their difference in loss of speed from air resistance, the time of the two bullets for 100 yards was almost the same, and the drop from the line of projection about 7½ inches in each.

The extent of drop of the respective bullets at eight equi-distant points in the 100 yards range will be seen by the following table, where the measurements are given to the second decimal, or hundredth part of an inch, in order that the variations from stage to stage may be readily traced:

FALL OF ·577 ELONGATED AND SPHERICAL BULLETS IN 100 YARDS.

| | 12½yds. | 25yds. | 37½yds. | 50yds. | 62½yds. | 75yds. | 87½yds. | 100yds. |
|---|---|---|---|---|---|---|---|---|
| Elongated... | 0·11in. | 0·43in. | 0·96in. | 1·74in. | 2·78in. | 4·06in. | 5·66in. | 7·57in. |
| Spherical ... | 0·07 | 0·32 | 0·77 | 1·46 | 2·45 | 3·77 | 5·48 | 7·64 |
| Difference... | 0·04 | 0·11 | 0·19 | 0·28 | 0·33 | 0·29 | 0·18 | —0·07 |

The drop of the elongated bullet, owing to its lower initial speed, is at first greater than that of the spherical ball, and the difference increases till beyond the middle of the range, the turning point in the trajectory of the elongated bullet occurring at about 52 yards, and that of the spherical ball about four yards further on; and as the long bullet has begun to drop from the culminating point of its trajectory, while the round ball has not yet reached it, the difference between them goes on increasing until the latter has passed its turning point. Subsequently the spherical ball is the slower of the two, and its drop increases accordingly, thereby reducing the difference step by step till they become even just before completing the 100 yards range, and the sphere is consequently a fraction lower than the other at the full distance. Beyond this point the spherical ball would lose ground more and more rapidly, and at 200 yards it would have dropped 49 inches below the line of projection, whereas the elongated bullet would only have dropped about 35 inches.

Supposing, then, that rifles were sighted for a fall of 7½ inches in 100 yards with each of the bullets, the difference in the heights of their trajectories would accord with the difference of drop at various points, as indicated in the foregoing table; and the spherical ball would have the higher trajectory up to nearly 100 yards, where it would drop below, as will be seen by the following figures:

HEIGHT OF TRAJECTORY OF ·577 SPHERICAL AND ELONGATED BULLETS IN 100 YARDS.

| | 12½yds. | 25yds. | 37½yds. | 50yds. | 62½yds. | 75yds. | 87½yds. | 100yds. |
|---|---|---|---|---|---|---|---|---|
| Spherical ... | 0·87in. | 1·56in. | 2·05in. | 2·29in. | 2·24in. | 1·86in. | 1·08in. | -- 0·14in. |
| Elongated ... | 0·83 | 1·45 | 1·86 | 2·01 | 1·91 | 1·57 | 0·90 | – 0·07 |
| Difference ... | 0·04 | 0·11 | 0·19 | 0·28 | 0·33 | 0·29 | 0·18 | -- 0·07 |

For a range of 200 yards, as the spherical drops 14 inches more than the elongated bullet, the same angle of elevation would no longer suit both; and if two rifles were sighted to correspond with the difference of fall, the trajectory of the Express would be about 10 inches at its highest point, whereas in that of the spherical ball the height would be very nearly 17 inches. The diagram (Fig. 16, p. 130) will represent the relative curves of the two bullets, *a c* being the trajectory of the elongated projectile, and *a c′* that of the spherical ball. When fired with the same elevation (line *a b*), the spherical ball, by reason of its higher velocity, is uppermost for about 100 yards, when, having lost its superiority of speed, and the time of flight having been equalised, its trajectory dips below that of the elongated bullet, which henceforth keeps the highest position. By the time it has gone about 170 yards, the spherical ball has dropped down below the line of sight (*a c*); and at the end of the 200 yards range it is about 14 inches lower than the elongated bullet. If the spherical ball were required to strike an object at 200 yards, the line of elevation would have to be raised 14 inches; and in that case the straight dotted line *a c′* would become the line of sight, and the distance between this and the curve *a c′* would be the height of trajectory.

## TRAJECTORIES OF EXPRESS RIFLES.

There may be said to be two very distinct types of rifles made for elongated bullets, viz., those for long heavy projectiles, with low muzzle-velocity, and those for comparatively short and light bullets with high initial speed—the former having low trajectories at long ranges, and the latter low trajectories at sporting distances. The last-mentioned may be subdivided into two or three varieties, according as the bullet is more or less light or hollow and the charge of powder more or less heavy. Where to draw the line as to what is or is not an "Express" rifle is a moot point about which opinions differ; but without attempting to say here what ought to be the nomenclature, it is clear that the same name has been applied to weapons differing considerably in weight of bullet, initial speed, and trajectory.

In the examples already given (pp. 101 and 111) of the velocity and energy of various Express bullets, there is considerable difficulty in making a comparison between them, in consequence of their varying in calibre, weight of bullet, length of barrel, and proportion of powder to lead. An endeavour will therefore here be made to put the various bores on an equal footing, by giving the weights of bullets which would have equal trajectories supposing that they had equal muzzle-velocities.

It is a not uncommon belief that the bullets of small-bore Express rifles have a flatter trajectory than those of large diameter; but, under equal conditions, the reverse of this is the case. It is only when the small bullets are *longer* than large ones that their trajectory is lower. When large and small are alike as to length, their trajectory is the same with equal initial velocity; and when there is equality in the proportion of length to diameter of bullet, the large bore has the advantage as to flatness of trajectory, supposing, as before, that they start with the same speed.

Let us take, by way of example, the Martini-Henry bullet, which is ·450in. in diameter, and 1·21in. (or a trifle more than 2⅗ diameters) in length. If bullets of other bores were made exactly proportionate with the Martini-Henry, their length and weight would be as shown in the following table, and the corresponding charge of powder required would be as here stated, supposing the same proportion of powder were used:

EQUAL PROPORTIONS OF LENGTH TO CALIBRE OF BULLET.

| Diameter of Bore. | Length of Bullet. | Weight of Bullet. | Corresponding Weight of Powder. |
|---|---|---|---|
| ·360 inch | 0·97 inch | 246 grains | 42 grains. |
| ·380 „ | 1·02 „ | 282 „ | 50 „ |
| ·400 „ | 1·05 „ | 337 „ | 60 „ |
| ·420 „ | 1·13 „ | 390 „ | 69 „ |
| **·450** „ | **1·21** „ | **480** „ | **85** „ |
| ·500 „ | 1·34 „ | 658 „ | 117 „ |
| ·577 „ | 1·56 „ | 1012 „ | 180 „ |

Here, the initial velocities being equal, the larger the bore the flatter would be the trajectory, as the weight of the bullet increases more rapidly than the surface opposed to the resistance of the atmosphere, and there is consequently less falling off in speed.

In the next table, however, the bullets are supposed to be equal in length; hence the area of resistance grows in the same proportion as the increase of weight. With equal initial velocity, the trajectory throughout is therefore the same, as they all lose speed at the same rate. Here it will be seen that, being all of the same length as the Martini-Henry bullet (nearly 1¼ inch), the small-bores would have to be lengthened beyond their proportion to calibre, in order to maintain an equally flat trajectory. Accordingly, their weight is increased beyond what is stated in the previous table; whereas those of larger bore are correspondingly diminished in length and in weight. This will be made more obvious if, instead of giving the length as equal in inch measurement, it is given in the number of diameters.

BULLETS OF EQUAL LENGTH BUT DIFFERENT CALIBRE.

| Diameter of Bore. | Length of Bullet. | Weight of Bullet. | Corresponding Weight of Powder. |
|---|---|---|---|
| ·360 inch | 3·36 diameters | 307 grains | 56 grains. |
| ·380 „ | 3·18 „ | 342 „ | 61 „ |
| ·400 „ | 3·02 „ | 379 „ | 67 „ |
| ·420 „ | 2·88 „ | 418 „ | 74 „ |
| **·450** „ | **2·69** „ | **480** „ | **85** „ |
| ·500 „ | 2·42 „ | 593 „ | 105 „ |
| ·577 „ | 2·11 „ | 789 „ | 140 „ |

It is not very probable, however, that sportsmen would use small-bores with such very long bullets. Most persons would prefer to use less lead in proportion to powder, and to get higher velocities. It may be as well, therefore, to see what bullets of different bore would correspond with those of ·450 of various weights.

The bullets in the next table would have equal trajectories with like muzzle-velocities. In each case, bullets of ·450 bore are taken as the type from which the others are calculated, and they are accordingly printed in more conspicuous figures. It may possibly be said that nobody would ever want, for sporting purposes, such heavy projectiles as many of these. The last line of the table, however, is inserted for the sake of comparison with the Martini; and the rest have their counterparts in rifles already made for sporting purposes, although some may not have come into general use. Thus, with reference to the heavy projectiles in the last line but one, where a 440gr. bullet of ·450 calibre is taken as the type, the ·400 bullet is here given as 348 grains, and, by turning back to page 16, it will be seen that Sir H. Halford mentions a ·400-bore rifle with 350gr. bullet as "the pleasantest and best rifle for deer." Further on in the same line of the present table, the weight of the ·577 bullet may seem enormous, but it does not very much exceed that used with Messrs. Holland's heavy rifle (M), which appears in the last line of the tables of Express rifles given on pp. 101 and 110.

WEIGHT OF BULLETS OF DIFFERENT CALIBRE HAVING SAME TRAJECTORIES WITH EQUAL VELOCITY.

| ·360 bore. | ·380 bore. | ·400 bore. | ·420 bore. | **·450** bore. | ·500 bore. | ·577 bore. |
|---|---|---|---|---|---|---|
| Grains. | Grains. | Grains. | Grains. | Grains. | Grains. | Grains. |
| 166 | 185 | 205 | 226 | **260** | 321 | 427 |
| 179 | 200 | 221 | 244 | **280** | 346 | 460 |
| 192 | 214 | 237 | 261 | **300** | 370 | 493 |
| 211 | 235 | 261 | 287 | **330** | 407 | 543 |
| 230 | 257 | 284 | 314 | **360** | 444 | 592 |
| 256 | 285 | 316 | 348 | **400** | 494 | 658 |
| 282 | 314 | 348 | 383 | **440** | 543 | 723 |
| 307 | 342 | 379 | 418 | **480** | 593 | 789 |

All bullets of the same dimensions do not, however, have equal muzzle-velocity, because some persons are content to use much smaller charges of powder than others. Let us see, then, what will be the difference in speed and drop of the foregoing series of bullets with different initial velocities.

We will begin with the light projectiles corresponding in type with the 260gr. bullet of ·450 calibre; and, as there is probably much greater variation in the powder-charges and in muzzle-velocity with light bullets than with those of a heavier character, it would be hardly satisfactory to take only one speed as a basis of comparison. It may be as well, therefore, to take 2000, 1900, and 1800 feet per second.

BULLETS OF SAME TYPE AS 260 GRS., ·450 BORE.

| | 2000 FT.-SEC. MUZZLE VELOCITY. | | | 1900 FT.-SEC. MUZZLE VELOCITY. | | | 1800 FT.-SEC. MUZZLE VELOCITY. | | |
|---|---|---|---|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | |
| Yards. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. |
| 50 | 1787 | 0 | 1·22 | 1696 | 0 | 1·47 | 1604 | 0 | 1·51 |
| 100 | 1592 | 0 | 5·48 | 1508 | 0 | 6·1 | 1423 | 0 | 6·8 |
| 150 | 1413 | 1 | 1·9 | 1338 | 1 | 3·5 | 1266 | 1 | 5·3 |
| 200 | 1257 | 2 | 4·1 | 1195 | 2 | 7·2 | 1137 | 2 | 10·9 |
| 250 | 1130 | 4 | 1·7 | 1081 | 4 | 7·3 | 1040 | 5 | 1·3 |
| 300 | 1036 | 6 | 8·8 | 1006 | 7 | 5 | 977 | 8 | 2 |
| 350 | 974 | 10 | 2 | 948 | 11 | 2 | 922 | 12 | 2 |
| 400 | 919 | 14 | 8 | 896 | 16 | 0 | 873 | 17 | 4 |
| 450 | 870 | 20 | 4 | 849 | 22 | 0 | 828 | 23 | 9 |
| 500 | 826 | 27 | 3 | 807 | 29 | 4 | 788 | 31 | 7 |
| Charge: 1 powder to about 1·8 lead. | | | | 1 powder to about 2·2 lead. | | | 1 powder to about 2·5 lead. | | |

An endeavour is made to give an idea of the charge of powder likely to produce the velocity stated at the head of the table; but this must only be considered as approximate, for all rifles will not give exactly corresponding results, even when the conditions are apparently alike. Large bores, too, will probably give rather higher results than small bores with the same proportion of powder, and long barrels will give greater velocity than short ones; but here the barrels are assumed to be of equal length, viz., 26 inches.

The question now arises, how far would these differences of velocity and drop affect the trajectory, or what would be the difference in the position of the bullet, if charges giving these different velocities were fired from a rifle sighted for one velocity. From the foregoing table we may see that, in a range of 100 yards, a difference of 100 ft.-sec. muzzle-velocity would make nearly three-quarters of an inch difference of drop; in 150 yards there would be about double this difference; in 200 yards more than four times as much; and so on. Consequently, if the rifle were sighted for, say, 150 yards, with a charge of powder giving 1900 ft.-sec. velocity, and were shot with a charge giving 2000, the bullet would strike about an inch and a half too high; or it would be nearly two inches too low if shot with a smaller charge, giving 1800 ft.-sec. velocity. If, however, the alteration of the charge produces a difference of "jump" in the rifle—as it certainly does in some cases—that cannot be estimated in this calculation. The amount of "drop" would not be affected by the jump, but the up and down position of the bullet on the target would be changed according to the extent of this muzzle disturbance, which would vary with the rifle.

Another mode of comparison may be made by means of independent trajectories, calculated from the drop of the respective bullets with their different velocities. These will now be given for every 50 yards from 100 up to 500 yards. It is not supposed, however, that sights for the whole of these distances would be applied to any one rifle; but, as different rifles may be sighted for different distances, the table may prove more useful than if the ranges were taken more widely apart. It will be seen that the trajectories for the three velocities at each range are grouped together, and the 0 shows the end of the range for which the rifle is supposed to be sighted—except in the 500 yards range, where the final 0 is omitted for want of space in the page. The greatest height of the trajectory is also given in the last column, as otherwise it could not be readily estimated in cases where there is no half-distance—*e.g.*, in the 150 yards range. The culminating point of the trajectory in this case occurs at about 80 yards. In the 500 yards range the greatest height occurs at about 300 yards with this bullet, and at less with heavier bullets; but there is no great difference between the height at the half-range and at the culminating point.

HEIGHT OF TRAJECTORIES OF BULLETS OF 260GR. TYPE IN RANGES FROM 100 TO 500 YARDS.

| Full Range and Muzzle Velocity | Height of Bullet at points in the Range, 50 yards apart. | | | | | | | | | Greatest Height of Trajectory. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50yds. | 100yds. | 150yds. | 200yds. | 250yds. | 300yds. | 350yds. | 400yds. | 450yds. | |
| Ft.-sec. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. |
| **100** | | | | | | | | | | |
| 2000 | 0 1·5 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 1·6 |
| 1900 | 0 1·6 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 1·7 |
| 1800 | 0 1·9 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 1·9 |
| **150** | | | | | | | | | | |
| 2000 | 0 3·4 | 0 3·8 | 0 | ... | ... | ... | ... | ... | ... | 0 4·1 |
| 1900 | 0 3·8 | 0 4·3 | 0 | ... | ... | ... | ... | ... | ... | 0 4·5 |
| 1800 | 0 4·3 | 0 4·8 | 0 | ... | ... | ... | ... | ... | ... | 0 5 |
| **200** | | | | | | | | | | |
| 2000 | 0 5·8 | 0 8·6 | 0 7·1 | 0 | ... | ... | ... | ... | ... | 0 8·7 |
| 1900 | 0 6·4 | 0 9·5 | 0 7·9 | 0 | ... | ... | ... | ... | ... | 0 9·7 |
| 1800 | 0 7·2 | 0 10·6 | 0 8·8 | 0 | ... | ... | ... | ... | ... | 0 10·8 |
| **250** | | | | | | | | | | |
| 2000 | 0 9 | 1 2 | 1 4 | 1 0 | 0 | ... | ... | ... | ... | 1 4 |
| 1900 | 0 10 | 1 4 | 1 6 | 1 1 | 0 | ... | ... | ... | ... | 1 6 |
| 1800 | 0 11 | 1 6 | 1 7 | 1 3 | 0 | ... | ... | ... | ... | 1 7 |
| **300** | | | | | | | | | | |
| 2000 | 1 0 | 1 10 | 2 2 | 2 2 | 1 6 | 0 | ... | ... | ... | 2 2 |
| 1900 | 1 2 | 2 0 | 2 5 | 2 4 | 1 7 | 0 | ... | ... | ... | 2 5 |
| 1800 | 1 4 | 2 2 | 2 8 | 2 6 | 1 8 | 0 | ... | ... | ... | 2 8 |
| **350** | | | | | | | | | | |
| 2000 | 1 4 | 2 5 | 3 3 | 3 6 | 3 2 | 2 0 | 0 | ... | ... | 3 6 |
| 1900 | 1 6 | 2 8 | 3 6 | 3 9 | 3 4 | 2 2 | 0 | ... | ... | 3 9 |
| 1800 | 1 7 | 2 11 | 3 9 | 4 1 | 3 7 | 2 4 | 0 | ... | ... | 4 1 |
| **400** | | | | | | | | | | |
| 2000 | 1 10 | 3 3 | 4 4 | 5 0 | 5 0 | 4 4 | 2 8 | 0 | ... | 5 1 |
| 1900 | 1 11 | 3 6 | 4 8 | 5 5 | 5 4 | 4 7 | 2 10 | 0 | ... | 5 6 |
| 1800 | 2 1 | 3 9 | 5 1 | 5 10 | 5 9 | 4 10 | 3 2 | 0 | ... | 5 11 |
| **450** | | | | | | | | | | |
| 2000 | 2 3 | 4 2 | 5 8 | 6 9 | 7 2 | 6 10 | 5 8 | 3 5 | 0 | 7 3 |
| 1900 | 2 4 | 4 5 | 6 1 | 7 2 | 7 7 | 7 3 | 5 11 | 3 7 | 0 | 7 8 |
| 1800 | 2 6 | 4 9 | 6 6 | 7 8 | 8 1 | 7 8 | 6 3 | 3 9 | 0 | 8 2 |
| **500** | | | | | | | | | | |
| 2000 | 2 8 | 5 0 | 7 0 | 8 7 | 9 6 | 9 7 | 8 10 | 7 1 | 4 2 | 9 7 |
| 1900 | 2 10 | 5 4 | 7 6 | 9 1 | 10 1 | 10 2 | 9 4 | 7 6 | 4 5 | 10 2 |
| 1800 | 3 1 | 5 9 | 8 0 | 10 7 | 10 8 | 10 9 | 9 11 | 7 11 | 4 8 | 10 9 |

### BULLETS OF SAME TYPE AS 280GRS., ·450 BORE.

| 1900 FT.-SEC. MUZZLE VELOCITY. | | | | 1800 FT.-SEC. MUZZLE VELOCITY. | | | |
|---|---|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | | Range. | Remaining Velocity. | Drop of Bullet. | |
| Yards. | Ft. per sec. | Ft. | in. | Yards. | Ft. per sec. | Ft. | in. |
| 50 | 1710 | 0 | 1·34 | 50 | 1617 | 0 | 1·5 |
| 100 | 1534 | 0 | 6·2 | 100 | 1448 | 0 | 6·7 |
| 150 | 1372 | 1 | 3 | 150 | 1297 | 1 | 5 |
| 200 | 1233 | 2 | 6 | 200 | 1171 | 2 | 10 |
| 250 | 1118 | 4 | 5 | 250 | 1069 | 4 | 11 |
| 300 | 1034 | 7 | 1 | 300 | 1003 | 7 | 10 |
| 350 | 976 | 10 | 8 | 350 | 949 | 11 | 8 |
| 400 | 925 | 15 | 2 | 400 | 900 | 16 | 7 |
| 450 | 878 | 20 | 10 | 450 | 856 | 22 | 7 |
| 500 | 837 | 27 | 9 | 500 | 816 | 30 | 0 |
| Charge: 1 powder to about 2·3 lead. | | | | Charge: 1 powder to about 2·6 lead. | | | |

It would be tedious to go through the various types of bullets with the same amount of fullness as is done on the previous two pages; and the figures there given show that, within moderate limits of change of velocity and alteration in weight of bullet, the variations of drop and differences in trajectory are comparatively small, and the divergences can be guessed at within a little when you have the weights, velocity, and drop of other bullets to take as standards to judge by. Accordingly, the "remaining velocities" and "drop" will, in the majority of cases, be calculated only from two muzzle velocities; but in two other instances, the three velocities and heights of trajectories will be given, for the purpose of affording standards of comparison.

In order to point out how these tables may be turned to account, let us assume that we have two rifles of ·400 and ·500 bore respectively, and that we wish to form an idea of what velocity and drop of bullet they would have at different ranges. The bullet generally used with our ·400 rifle weighs, say, about 220 grains, and that of the ·500 about 440 grains.

Looking at the table on page 142, we find that our ·400 bullet is similar in type to the ·450 of 280 grains, and that our ·500 bullet is much about the same as the ·450 of 360 grains. Hence we take as our means of comparison, in the former case, the table opposite, and for the 500-bore we refer to the table of 360gr. type given on page 150.

If we know, from chronograph results, or from the process of calculation hereafter described, what is about the muzzle velocity of the respective rifles, we may find that they come within a moderate difference from one or other of the muzzle velocities given at the head of the table we have to use, and accordingly we choose that which is nearest; or supposing that, in the case of the ·400 bullet, we know that its muzzle velocity is about 1850 ft.-sec., we may take the medium between 1900 and 1800, and see at a glance that at, say, 200 yards, the remaining velocity would be about 1200 ft.-sec., and the drop about 2ft. 8in.; and so on with other distances. If we do not know what the muzzle velocity is, we may yet perhaps be able to form an approximate notion by reference to the charge of powder. The ·400 bullet of 220 grains is shot with, say, 3¼ or 3½ drams of powder. Referring to the table on page 99, we see that the former charge is equal to about 89grs., and the latter to about 96grs.; and dividing the grains of lead by the grains of powder, we find that 3¼drs. would give the proportion of about 1 to 2·5, and 3½drs. of about 1 to 2·3; so it may be assumed that the muzzle velocity of the former would be rather over 1800 ft.-sec., and of the latter about 1900 ft.-sec.

One thing, however, it will not be safe to assume, viz., that if we alter the charge from 3¼drs. to 3½drs., or *vice versâ*, and thus raise or diminish the velocity by 100 or any other number of feet per second, the difference on the target will be only the number of inches shown in these tables. Such would be the case if all conditions remained exactly the same except the mere alteration of speed; and such, indeed, is the effect when, as the chronograph shows, there are variations of muzzle-velocity with exactly the same charges. But when we alter the quantity of powder, the conditions of explosion are also changed; a different degree of "jump" is set up in the barrel, and the effect of this change of jump does not run on the same lines as the effect of simple alteration of speed. Thus, referring to the next table, we find that, in 100 yards, there is less than one inch difference of drop produced by 100 ft.-sec. change of initial speed, but that at 500 yards the difference is nearly 2½ feet. There might be a difference in jump such as would just compensate for the difference of drop at one range, but would have by no means the same effect at the other; for such a change of jump as would produce 30 inches difference in 500 yards would make 6 inches difference at 100 yards, and, as the gravity drop makes only about 1 inch difference in the latter range, the bullet would be 5 inches above or below the expected position on the target, and the marksman might be puzzled to account for it.

### Bullets of same Type as 300 grs., ·450 bore.

| | 1900 ft.-sec. Muzzle Velocity. | | | 1800 ft.-sec. Muzzle Velocity. | | | 1700 ft.-sec. Muzzle Velocity. | | |
|---|---|---|---|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | |
| Yards. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. |
| 50 | 1722 | 0 | 1·32 | 1629 | 0 | 1·49 | 1536 | 0 | 1·7 |
| 100 | 1556 | 0 | 5·9 | 1470 | 0 | 6·8 | 1384 | 0 | 7·4 |
| 150 | 1403 | 1 | 2·7 | 1325 | 1 | 4·4 | 1252 | 1 | 7 |
| 200 | 1267 | 2 | 5 | 1202 | 2 | 9 | 1141 | 3 | 1 |
| 250 | 1154 | 4 | 3 | 1100 | 4 | 9 | 1053 | 5 | 3 |
| 300 | 1062 | 9 | 3 | 1027 | 7 | 6 | 995 | 8 | 4 |
| 350 | 1002 | 10 | 2 | 973 | 11 | 2 | 945 | 12 | 4 |
| 400 | 951 | 14 | 6 | 926 | 15 | 10 | 900 | 17 | 4 |
| 450 | 906 | 19 | 11 | 882 | 21 | 7 | 859 | 23 | 6 |
| 500 | 864 | 26 | 5 | 843 | 28 | 7 | 822 | 31 | 0 |
| **Charge:** 1 powder to about 2·3 lead. | | | | 1 powder to about 2·5 lead. | | | 1 powder to about | | |

HEIGHT OF TRAJECTORIES OF BULLETS OF 300GR. TYPE, IN RANGES 100 TO 500 YARDS.

| Full Range and Muzzle Velocity | Height of Bullet at points in the Range, 50 yards apart. | | | | | | | | | Greatest Height of Trajectory. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50yds. | 100yds. | 150yds. | 200yds. | 250yds. | 300yds. | 350yds. | 400yds. | 450yds, | |
| Ft.-sec. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. |
| **100** | | | | | | | | | | |
| 1900 | 0 1·6 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 1·6 |
| 1800 | 0 1·9 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 1·9 |
| 1700 | 0 2·0 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 2·0 |
| **150** | | | | | | | | | | |
| 1900 | 0 3·6 | 0 3·9 | 0 | ... | ... | ... | ... | ... | ... | 0 4·3 |
| 1800 | 0 4·0 | 0 4·2 | 0 | ... | ... | ... | ... | ... | ... | 0 4·7 |
| 1700 | 0 4·5 | 0 4·9 | 0 | ... | ... | ... | ... | ... | ... | 0 5·2 |
| **200** | | | | | | | | | | |
| 1900 | 0 6·0 | 0 8·7 | 0 7·2 | 0 | ... | ... | ... | ... | ... | 0 8·8 |
| 1800 | 0 6·7 | 0 9·6 | 0 8·1 | 0 | ... | ... | ... | ... | ... | 0 9·7 |
| 1700 | 0 7·5 | 0 10·9 | 0 9 | 0 | ... | ... | ... | ... | ... | 0 11·0 |
| **250** | | | | | | | | | | |
| 1900 | 0 9 | 1 2 | 1 4 | 1 0 | 0 | ... | ... | ... | ... | 1 4 |
| 1800 | 0 10 | 1 4 | 1 6 | 1 1 | 0 | ... | ... | ... | ... | 1 6 |
| 1700 | 0 11 | 1 6 | 1 8 | 1 2 | 0 | ... | ... | ... | ... | 1 8 |
| **300** | | | | | | | | | | |
| 1900 | 1 0 | 1 9 | 2 2 | 2 1 | 1 5 | 0 | ... | ... | ... | 2 2 |
| 1800 | 1 1 | 1 11 | 2 5 | 2 4 | 1 7 | 0 | ... | ... | ... | 2 5 |
| 1700 | 1 3 | 2 2 | 2 7 | 2 6 | 1 8 | 0 | ... | ... | ... | 2 7 |
| **350** | | | | | | | | | | |
| 1900 | 1 4 | 2 5 | 3 2 | 3 5 | 3 0 | 1 11 | 0 | ... | ... | 3 5 |
| 1800 | 1 6 | 2 8 | 3 5 | 3 8 | 3 3 | 2 1 | 0 | ... | ... | 3 8 |
| 1700 | 1 7 | 2 11 | 3 9 | 4 0 | 3 6 | 2 3 | 0 | ... | ... | 4 0 |
| **400** | | | | | | | | | | |
| 1900 | 1 8 | 3 2 | 4 2 | 4 10 | 4 10 | 4 1 | 2 6 | 0 | ... | 4 11 |
| 1800 | 1 10 | 3 5 | 4 6 | 5 2 | 5 2 | 4 4 | 2 8 | 0 | ... | 5 3 |
| 1700 | 2 3 | 3 9 | 4 11 | 5 7 | 5 7 | 4 8 | 2 10 | 0 | ... | 5 8 |
| **450** | | | | | | | | | | |
| 1900 | 2 1 | 3 11 | 5 5 | 6 5 | 6 10 | 6 6 | 5 4 | 3 3 | 0 | 6 10 |
| 1800 | 2 3 | 4 3 | 5 10 | 6 11 | 7 3 | 6 11 | 5 7 | 3 4 | 0 | 7 3 |
| 1700 | 2 6 | 4 7 | 6 3 | 7 5 | 7 9 | 7 4 | 6 0 | 3 6 | 0 | 7 9 |
| **500** | | | | | | | | | | |
| 1900 | 2 6 | 4 10 | 6 8 | 8 2 | 9 0 | 9 1 | 8 4 | 6 8 | 3 10 | 9 1 |
| 1800 | 2 9 | 5 2 | 7 2 | 8 9 | 9 7 | 9 8 | 8 10 | 7 0 | 4 1 | 9 8 |
| 1700 | 3 0 | 5 7 | 7 9 | 9 4 | 10 2 | 10 3 | 9 4 | 7 5 | 4 4 | 10 3 |

By comparing with page 145, we see that an increase of 40 grains gives in long ranges nearly the same trajectory as 260gr. bullet with 200 ft.-sec. more velocity.

BULLETS OF SAME TYPE AS 330GRS., ·450 BORE.

| 1800 FT.-SEC. MUZZLE VELOCITY. | | | | 1700 FT.-SEC. MUZZLE VELOCITY. | | | |
|---|---|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | | Range. | Remaining Velocity. | Drop of Bullet. | |
| Yards. | Ft. per sec. | Ft. | in. | Yards. | Ft. per sec. | Ft. | in. |
| 50 | 1645 | 0 | 1·5 | 50 | 1550 | 0 | 1·7 |
| 100 | 1498 | 0 | 6·5 | 100 | 1411 | 0 | 7·3 |
| 150 | 1363 | 1 | 4 | 150 | 1286 | 1 | 6 |
| 200 | 1244 | 2 | 7 | 200 | 1179 | 2 | 11 |
| 250 | 1144 | 4 | 6 | 250 | 1089 | 5 | 1 |
| 300 | 1062 | 7 | 2 | 300 | 1025 | 7 | 11 |
| 350 | 1007 | 10 | 7 | 350 | 977 | 11 | 8 |
| 400 | 960 | 14 | 11 | 400 | 933 | 16 | 5 |
| 450 | 917 | 20 | 4 | 450 | 892 | 22 | 3 |
| 500 | 878 | 26 | 10 | 500 | 855 | 29 | 3 |
| Charge: 1 powder to about 2·8 lead. | | | | Charge: 1 powder to about 3 lead. | | | |

Taking each of these, and comparing them with the same muzzle velocity in the type of bullet above or below it in weight, we find the differences are not so wide apart but that approximate estimates may be formed of other bullets intermediate in weight, as the variations may be only a few feet in velocity or a few inches in drop.

BULLETS OF SAME TYPE AS 360 GRS., ·450 BORE.

| 1800 FT.-SEC. MUZZLE VELOCITY. | | | | 1700 FT.-SEC. MUZZLE VELOCITY. | | | 1600 FT.-SEC. MUZZLE VELOCITY. | | |
|---|---|---|---|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | |
| Yards. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. |
| 50 | 1657 | 0 | 1·46 | 1563 | 0 | 1·55 | 1468 | 0 | 1·86 |
| 100 | 1522 | 0 | 6·36 | 1433 | 0 | 7·15 | 1347 | 0 | 8·1 |
| 150 | 1395 | 1 | 5·4 | 1315 | 1 | 5·6 | 1240 | 1 | 7·9 |
| 200 | 1282 | 2 | 6·5 | 1212 | 2 | 10 | 1148 | 3 | 2·6 |
| 250 | 1184 | 4 | 4 | 1124 | 4 | 10 | 1070 | 5 | 5·5 |
| 300 | 1100 | 6 | 10 | 1052 | 7 | 7 | 1017 | 8 | 5·6 |
| 350 | 1036 | 10 | 1 | 1004 | 11 | 2 | 973 | 12 | 5 |
| 400 | 991 | 14 | 2 | 961 | 15 | 8 | 933 | 17 | 3 |
| 450 | 949 | 19 | 3 | 922 | 21 | 2 | 896 | 23 | 2 |
| 500 | 911 | 25 | 5 | 886 | 28 | 9 | 862 | 30 | 3 |
| Charge: 1 powder to about 2·5 lead. | | | | 1 powder to about 3 lead. | | | 1 powder to about 4 lead. | | |

HEIGHT OF TRAJECTORIES OF BULLETS OF 360GR. TYPE, FROM 100 TO 500 YARDS.

| Full Range and Muzzle Velocity | Height of Bullet at points in Range, 50 yards apart. | | | | | | | | | Greatest Height of Trajectory. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50yds. | 100yds. | 150yds. | 200yds. | 250yds. | 300yds. | 350yds. | 400yds. | 450yds. | |
| Ft.-sec. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. | Ft. in. |
| **100** | | | | | | | | | | |
| 1800 | 0 1·7 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 1·8 |
| 1700 | 0 2 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 2·1 |
| 1600 | 0 2·2 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 2·3 |
| **150** | | | | | | | | | | |
| 1800 | 0 3·8 | 0 4·1 | 0 | ... | ... | ... | ... | ... | ... | 0 4·6 |
| 1700 | 0 4·3 | 0 4·6 | 0 | ... | ... | ... | ... | ... | ... | 0 5·0 |
| 1600 | 0 4·8 | 0 5·2 | 0 | ... | ... | ... | ... | ... | ... | 0 5·6 |
| **200** | | | | | | | | | | |
| 1800 | 0 6·1 | 0 8·9 | 0 7·2 | 0 | ... | ... | ... | ... | ... | 0 9.1 |
| 1700 | 0 6·9 | 0 9·9 | 0 8·0 | 0 | ... | ... | ... | ... | ... | 0 10.1 |
| 1600 | 0 7·8 | 0 11·2 | 0 9·0 | 0 | ... | ... | ... | ... | ... | 0 11.4 |
| **250** | | | | | | | | | | |
| 1800 | 0 8·9 | 1 2·4 | 1 3·5 | 0 11·1 | 0 | ... | ... | ... | ... | 1 4 |
| 1700 | 0 10 | 1 4·1 | 1 5·4 | 1 0·4 | 0 | ... | ... | ... | ... | 1 6 |
| 1600 | 0 11·3 | 1 6·0 | 1 7·6 | 1 1·8 | 0 | ... | ... | ... | ... | 1 8 |
| **300** | | | | | | | | | | |
| 1800 | 1 0 | 1 9 | 2 1 | 2 0 | 1 4 | 0 | ... | ... | ... | 2 2 |
| 1700 | 1 2 | 1 11 | 2 4 | 2 3 | 1 6 | 0 | ... | ... | ... | 2 5 |
| 1600 | 1 3 | 2 2 | 2 7 | 2 5 | 1 7 | 0 | ... | ... | ... | 2 8 |
| **350** | | | | | | | | | | |
| 1800 | 1 4 | 2 4 | 3 0 | 3 3 | 2 9 | 1 10 | 0 | ... | ... | 3 4 |
| 1700 | 1 6 | 2 7 | 3 4 | 3 6 | 3 2 | 2 0 | 0 | ... | ... | 3 7 |
| 1600 | 1 7 | 2 10 | 3 7 | 3 10 | 3 5 | 2 2 | 0 | ... | ... | 3 11 |
| **400** | | | | | | | | | | |
| 1800 | 1 8 | 3 0 | 4 0 | 4 7 | 4 7 | 3 10 | 2 4 | 0 | ... | 4 7 |
| 1700 | 1 10 | 3 4 | 4 5 | 5 0 | 4 11 | 4 2 | 2 6 | 0 | ... | 5 0 |
| 1600 | 2 0 | 3 8 | 4 10 | 5 5 | 5 4 | 4 5 | 2 8 | 0 | ... | 5 5 |
| **450** | | | | | | | | | | |
| 1800 | 2 0 | 3 9 | 5 1 | 6 0 | 6 5 | 6 1 | 4 11 | 2 11 | 0 | 6 5 |
| 1700 | 2 3 | 4 1 | 5 7 | 6 7 | 6 10 | 6 6 | 5 3 | 3 2 | 0 | 6 10 |
| 1600 | 2 5 | 4 6 | 6 1 | 7 1 | 7 5 | 6 11 | 5 7 | 3 5 | 0 | 7 5 |
| **500** | | | | | | | | | | |
| 1800 | 2 5 | 4 7 | 6 3 | 7 7 | 8 4 | 8 5 | 7 8 | 6 1 | 3 7 | 8 5 |
| 1700 | 2 8 | 4 11 | 6 10 | 8 3 | 9 0 | 9 1 | 8 3 | 6 6 | 3 10 | 9 1 |
| 1600 | 2 10 | 5 4 | 7 5 | 8 10 | 9 7 | 9 8 | 8 9 | 6 10 | 4 1 | 9 8 |

Weight again tells; and we find that, when the range is long, the 360gr. bullet gives much the same trajectory with 1600 ft.-sec. muzzle velocity as the 260gr. bullet (page 145) gives with 400ft. more speed; while, at short ranges, the effect is much about the same as 200ft. difference of initial speed. The 300 gr.-bullet (page 149), as might be expected, gives medium results; the long-range trajectories being very similar to those of 260grs. and 360grs. having 200ft. higher or lower speed, and the short ranges having about half that difference.

BULLETS OF SAME TYPE AS 400GRS., ·450 BORE.

| 1600 FT.-SEC. MUZZLE VELOCITY. | | | 1500 FT.-SEC. MUZZLE VELOCITY. | | |
|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | Range. | Remaining Velocity. | Drop of Bullet. |
| Yards. | Ft. per sec. | Ft. in. | Yards. | Ft. per sec. | Ft. in. |
| 50 | 1481 | 0 1·84 | 50 | 1387 | 0 2·09 |
| 100 | 1370 | 0 7·9 | 100 | 1286 | 0 9·1 |
| 150 | 1270 | 1 7 | 150 | 1196 | 1 10 |
| 200 | 1183 | 3 1 | 200 | 1118 | 3 6 |
| 250 | 1107 | 5 3 | 250 | 1054 | 5 11 |
| 300 | 1046 | 8 1 | 300 | 1010 | 9 1 |
| 350 | 1003 | 11 10 | 350 | 971 | 13 2 |
| 400 | 965 | 16 5 | 400 | 935 | 18 2 |
| 450 | 929 | 21 11 | 450 | 896 | 25 3 |
| 500 | 896 | 28 6 | 500 | 870 | 31 4 |
| Charge: 1 powder to about 4 of lead. | | | Charge: 1 powder to about 4·5 of lead. | | |

BULLETS OF SAME TYPE AS 440GRS., ·450 BORE.

| 1500 FT.-SEC. MUZZLE VELOCITY. | | | 1400 FT.-SEC. MUZZLE VELOCITY. | | |
|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | Range. | Remaining Velocity. | Drop of Bullet. |
| Yards. | Ft. per sec. | Ft. in. | Yards. | Ft. per sec. | Ft. in. |
| 50 | 1397 | 0 2·08 | 50 | 1306 | 0 2·4 |
| 100 | 1303 | 0 8·9 | 100 | 1222 | 0 10·2 |
| 150 | 1219 | 1 9·5 | 150 | 1147 | 2 1 |
| 200 | 1145 | 3 5 | 200 | 1083 | 3 11 |
| 250 | 1081 | 5 9 | 250 | 1034 | 6 6 |
| 300 | 1033 | 8 9 | 300 | 996 | 9 10 |
| 350 | 995 | 12 8 | 350 | 962 | 14 1 |
| 400 | 961 | 17 5 | 400 | 929 | 19 3 |
| 450 | 928 | 23 2 | 450 | 899 | 25 6 |
| 500 | 898 | 29 11 | 500 | 870 | 32 10 |
| Charge: 1 powder to about 4·5 of lead. | | | Charge: 1 powder to about 5 of lead. | | |

BULLETS OF SAME TYPE AS MARTINI-HENRY, 480GRS., ·450 BORE.

| | 1400 FT.-SEC. MUZZLE VELOCITY. | | | 1350 FT.-SEC. MUZZLE VELOCITY. | | | 1300 FT.-SEC. MUZZLE VELOCITY. | | |
|---|---|---|---|---|---|---|---|---|---|
| Range. | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | | Remaining Velocity. | Drop of Bullet. | |
| Yards. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. | Ft. per sec. | Ft. | in. |
| 100 | 1235 | 0 | 10·1 | 1195 | 0 | 10·8 | 1153 | 0 | 11·9 |
| 200 | 1103 | 3 | 9 | 1072 | 4 | 1 | 1045 | 4 | 4 |
| 300 | 1015 | 9 | 7 | 996 | 10 | 2 | 976 | 10 | 10 |
| 400 | 950 | 18 | 9 | 934 | 19 | 8 | 917 | 20 | 7 |
| 500 | 894 | 31 | 9 | 879 | 33 | 3 | 864 | 35 | 0 |
| 600 | 844 | 49 | 3 | 831 | 51 | 7 | 817 | 54 | 1 |
| 700 | 799 | 72 | 0 | 787 | 75 | 2 | 775 | 78 | 5 |
| 800 | 757 | 100 | 9 | 746 | 104 | 10 | 735 | 109 | 2 |
| 900 | 718 | 136 | 3 | 708 | 141 | 6 | 697 | 147 | 4 |
| 1000 | 683 | 179 | 3 | 672 | 186 | 0 | 661 | 193 | 5 |

**Charge:** 1 powder to about 5·3 lead. 1 powder to about 5·6 lead. 1 powder to about 6 lead.

These tables, as before observed, represent merely the natural drop from gravitation in accordance with the time taken by the bullet to traverse each particular range. This is all that can be accounted for on the theoretical side of the question. On the practical side, there are other matters which the maker of the rifle must necessarily take into consideration, or he would produce but a very sorry result. He has to meet the peculiar "jump" of each weapon; and the *apparent* drop for which he regulates the rifle may therefore be more or less than the *real* drop indicated by the tables. These calculations, however, are not intended to be mere theoretical curiosities. It is hoped that they may prove of some practical service to the maker, as well as the user, of the rifle, by enabling them to meet this condition of things. A comparison of the results actually obtained at the target with the amount of natural drop shown in the tables, will give an idea, when different charges are used, of how much of the difference of position of the bullets is due to jump, and how much to the altered velocity of the bullet.

## THE CALCULATION OF TRAJECTORIES.

The trajectory of a bullet may be calculated either from the amount of its drop in a given distance, or from its muzzle velocity; and if the latter be known, the former may be estimated, and *vice versâ*—always supposing that the diameter and weight, as well as the shape of the projectile, have been ascertained.

If a chronograph is available, that, of course, is an authoritative means of getting the bullet's velocity; and the method afterwards described is only a substitute for obtaining approximate results, where a proper instrument cannot be obtained. The chronograph does not, however, directly tell the speed with which the shot leaves the muzzle; it merely records the amount of time taken to traverse a given distance, and shows the *mean* velocity for such distance. Thus, if we know what fraction of a second of time was taken by the bullet in passing from the muzzle of the gun to a screen placed 20 yards distant, and we divide the 20 yards, or 60 feet, by this fraction, we ascertain the velocity in feet per second. But, inasmuch as the bullet loses speed in the 20 yards, from its encounter with the atmosphere, the chronograph record neither shows the velocity with which the bullet left the gun nor that with which it struck the screen; it gives, in fact, the average velocity, and this is equivalent to the actual speed of the bullet at the mean distance of 10 yards. Perhaps, however, it would be more strictly correct to say that the mean velocity of the full range very closely approximates to the actual speed at half-range; but the divergence from strict accuracy is so small that it may be disregarded in short ranges. If the resistance of the atmosphere varied exactly in accordance with the cube of the velocity, the average speed at one distance would exactly represent the real velocity at half that distance; but, inasmuch as the ratio varies somewhat, being less than the cube when the velocity either rises much above or falls much below 1100 feet per second, there is a consequent amount of variation, which tells most with very light projectiles, at high velocities, in long ranges; but even with these the difference is comparatively trifling, and, for all practical purposes, it may be left out of consideration.

We will suppose, however, in the first place, that the muzzle velocity is known, and that we wish to find out what would be the "remaining velocity" of the projectile at any given distance. Having done this, we can easily reverse the process, and ascertain the muzzle velocity from the mean time.

But we can do nothing without the tables invented by Professor Bashforth, and some of these, which apply to elongated projectiles with ogival heads, are accordingly quoted in the ensuing pages. It would be beyond the scope of this book to enter into a description of the manner in which these tables. were framed. Anyone wishing for particulars on this subject must be referred to Mr. Bashforth's volume and supplement, or to the Government blue books containing his reports to the War Office. The tables given over-leaf are copied from the "Final Report" mentioned below. The titles of these books and reports are as follows:

"A Mathematical Treatise on the Motion of Projectiles, founded chiefly on the Results of Experiments made with the Author's Chronograph." By Francis Bashforth, B.D., Professor of Applied Mathematics to the Advanced Class of Royal Artillery Officers, Woolwich. London: Asher & Co., 17, Bedford-street, Covent-garden. 1873.

"Supplement to a Mathematical Treatise on the Motion of Projectiles." By Francis Bashforth, &c. London: Asher & Co. 1881.

"Reports on Experiments made with the Bashforth Chronograph to Determine the Resistance of the Air to the Motion of Projectiles." 1865–1870. London: W. Clowes & Sons, and other booksellers.

"Final Report on Experiments made with the Bashforth Chronograph to Determine the Resistance of the Air to Elongated Projectiles." 1878–80. London: W. Clowes & Sons, &c.

## *A General Table of Values of* $\frac{d^2}{w}t$ *for Ogival-headed Shot.*

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 10 | 75·399 | 77·111 | 78·790 | 80·437 | 82·052 | 83·636 | 85·190 | 86·715 | 88·212 | 89·682 | 1·584 |
| 11 | 91·125 | 92·542 | 93·934 | 95·301 | 96·644 | 97·964 | 99·261 | *00·536 | *01·789 | *03·021 | 1·320 |
| 12 | 1 04·232 | 05·423 | 06·595 | 07·748 | 08·883 | 09·999 | 11·097 | 12·178 | 13·243 | 14·291 | 1·116 |
| 13 | 1 15·323 | 16·339 | 17·340 | 18·326 | 19·297 | 20·254 | 21·196 | 22·124 | 23·039 | 23·941 | ·957 |
| 14 | 24·830 | 25·706 | 26·570 | 27·422 | 28·262 | 29·091 | 29·908 | 30·714 | 31·509 | 32·294 | ·829 |
| 15 | 33·068 | 33·832 | 34·586 | 35·331 | 36·066 | 36·792 | 37·508 | 38·215 | 38·913 | 39·602 | ·726 |
| 16 | 1 40·283 | 40·955 | 41·618 | 42·273 | 42·920 | 43·559 | 44·190 | 44·818 | 45·429 | 46·038 | ·639 |
| 17 | 46·640 | 47·235 | 47·823 | 48·404 | 48·978 | 49·546 | 50·107 | 50·662 | 51·211 | 51·754 | ·568 |
| 18 | 52·291 | 52·822 | 53·347 | 53·867 | 54·381 | 54·890 | 55·393 | 55·890 | 56·382 | 56·869 | ·509 |
| 19 | 1 57·351 | 57·828 | 58·300 | 58·767 | 59·229 | 59·686 | 60·138 | 60·586 | 61·029 | 61·468 | ·457 |
| 20 | 61·902 | 62·332 | 62·758 | 63·180 | 63·598 | 64·012 | 64·422 | 64·828 | 65·230 | 65·628 | ·414 |
| 21 | 66·022 | 66·412 | 66·798 | 67·181 | 67·560 | 67·936 | 68·308 | 68·676 | 69·041 | 69·403 | ·376 |
| 22 | 1 69·762 | 70·118 | 70·470 | 70·819 | 71·165 | 71·508 | 71·848 | 72·185 | 72·519 | 72·850 | ·343 |
| 23 | 73·179 | 73·505 | 73·828 | 74·148 | 74·465 | 74·780 | 75·092 | 75·401 | 75·708 | 76·012 | ·315 |
| 24 | 76·314 | 76·613 | 76·909 | 77·203 | 77·494 | 77·783 | 78·070 | 78·354 | 78·636 | 78·916 | ·289 |
| 25 | 1 79·194 | 79·470 | 79·743 | 80·014 | 80·283 | 80·550 | 80·815 | 81·078 | 81·339 | 81·598 | ·267 |
| 26 | 81·855 | 82·110 | 82·363 | 82·614 | 82·863 | 83·110 | 83·355 | 83·598 | 83·839 | 84·079 | ·247 |
| 27 | 84·317 | 84·553 | 84·787 | 85·020 | 85·251 | 85·481 | 85·709 | 85·935 | 86·160 | 86·382 | ·230 |
| 28 | 1 86·604 | 86·824 | 87·042 | 87·259 | 87·474 | 87·688 | 87·900 | 88·111 | 88·320 | 88·528 | ·214 |
| 29 | 88·734 | 88·939 | 89·143 | 89·345 | 89·546 | 89·745 | 89·943 | 90·140 | 90·335 | 90·529 | ·199 |
| 30 | 90·721 | 90·912 | 91·102 | 91·291 | 91·478 | 91·664 | 91·849 | 92·033 | 92·216 | 92·397 | ·186 |
| 31 | 1 92·577 | 92·756 | 92·934 | 93·111 | 93·287 | 98·461 | 93·634 | 93·806 | 93·971 | 94·147 | ·174 |
| 32 | 94·316 | 94·484 | 94·651 | 94·817 | 94·982 | 95·146 | 95·309 | 95·471 | 95·632 | 95·792 | ·164 |
| 33 | 95·951 | 96·109 | 96·266 | 96·422 | 96·577 | 96·731 | 96·884 | 97·036 | 97·187 | 97·338 | ·154 |
| 34 | 1 97·488 | 97·637 | 97·785 | 97·932 | 98·078 | 98·223 | 98·367 | 98·510 | 98·652 | 98·794 | ·145 |
| 35 | 98·935 | 99·075 | 99·214 | 99·352 | 99·490 | 99·627 | 99·763 | 99·898 | *00·032 | *00·166 | ·137 |
| 36 | 2 00·299 | 00·431 | 00·562 | 00·692 | 00·822 | 00·951 | 01·079 | 01·206 | 01·333 | 01·459 | ·129 |
| 37 | 2 01·585 | 01·710 | 01·834 | 01·957 | 02·080 | 02·202 | 02·323 | 02·443 | 02·563 | 02·682 | ·122 |
| 38 | 02·801 | 02·919 | 03·036 | 03·152 | 03·268 | 03·383 | 03·497 | 03·610 | 03·723 | 03·835 | ·115 |
| 39 | 03·947 | 04·058 | 04·168 | 04·278 | 04·387 | 04·496 | 04·604 | 04·711 | 04·818 | 04·924 | ·109 |
| 40 | 20 5·0299 | 5·1349 | 5·2393 | 5·3432 | 5·4466 | 5·5494 | 5·6517 | 5·7534 | 5·8546 | 5·9553 | ·1028 |
| 41 | 6·0554 | 6·1550 | 6·2540 | 6·3525 | 6·4505 | 6·5480 | 6·6450 | 6·7414 | 6·8373 | 6·9327 | ·0975 |
| 42 | 7·0276 | 7·1220 | 7·2159 | 7·3093 | 7·4022 | 7·4947 | 7·5867 | 7·6782 | 7·7693 | 7·8599 | ·0925 |
| 43 | 20 7·9501 | 8·0398 | 8·1291 | 8·2179 | 8·3063 | 8·3942 | 8·4817 | 8·5687 | 8·6553 | 8·7415 | ·0879 |
| 44 | 8·8272 | 8·9125 | 8·9974 | 9·0819 | 9·1660 | 9·2497 | 9·3330 | 9·4159 | 9·4984 | 9·5805 | ·0837 |
| 45 | 9·6622 | 9·7435 | 9·8244 | 9·9050 | 9·9852 | *0·0651 | *0·1446 | *0·2237 | *0·3025 | *0·3809 | ·0799 |
| 46 | 21 0·4590 | 0·5367 | 0·6140 | 0·6910 | 0·7677 | 0·8440 | 0·9200 | 0·9956 | 1·0709 | 1·1459 | ·0763 |
| 47 | 1·2205 | 1·2948 | 1·3687 | 1·4423 | 1·5156 | 1·5886 | 1·6613 | 1·7336 | 1·8056 | 1·8773 | ·0730 |
| 48 | 1·9487 | 2·0198 | 2·0906 | 2·1611 | 2·2313 | 2·3012 | 2·3708 | 2·4401 | 2·5091 | 2·5779 | ·0699 |
| 49 | 21 2·6464 | 2·7146 | 2·7825 | 2·8501 | 2·9174 | 2·9845 | 3·0513 | 3·1178 | 3·1841 | 3·2501 | ·0671 |
| 50 | 3·3159 | 3·3814 | 3·4466 | 3·5116 | 3·5763 | 3·6608 | 3·7050 | 3·7689 | 3·8326 | 3·8960 | ·0645 |
| 51 | 3·9592 | 4·0221 | 4·0848 | 4·1472 | 4·2094 | 4·2713 | 4·3330 | 4·3944 | 4·4556 | 4·5165 | ·0619 |
| 52 | 21 4·5772 | 4·6377 | 4·6979 | 4·7579 | 4·8177 | 4·8773 | 4·9367 | 4·9958 | 5·0547 | 5·1134 | ·0596 |
| 53 | 5·1719 | 5·2302 | 5·2882 | 5·3460 | 5·4036 | 5·4610 | 5·5182 | 5·5752 | 5·6320 | 5·6886 | ·0574 |
| 54 | 5·7450 | 5·8012 | 5·8572 | 5·9130 | 5·9686 | 6·0240 | 6·0792 | 6·1342 | 6·1890 | 6·2436 | ·0554 |
| 55 | 21 6·2980 | 6·3522 | 6·4062 | 6·4600 | 6·5136 | 6·5670 | 6·6202 | 6·6732 | 6·7260 | 6·7786 | ·0534 |
| 56 | 6·8311 | 6·8834 | 6·9355 | 6·9874 | 7·0391 | 7·0907 | 7·1421 | 7·1933 | 7·2444 | 7·2953 | ·0516 |
| 57 | 7·3460 | 7·3965 | 7·4469 | 7·4971 | 7·5471 | 7·5970 | 7·6467 | 7·6962 | 7·7456 | 7·7948 | ·0499 |
| 58 | 21 7·8438 | 7·8928 | 7·9417 | 7·9904 | 8·0389 | 8·0873 | 8·1356 | 8·1837 | 8·2316 | 8·2793 | ·0483 |
| 59 | 8·3271 | 8·3746 | 8·4220 | 8·4692 | 8·5163 | 8·5632 | 8·6100 | 8·6566 | 8·7031 | 8·7494 | ·0468 |
| 60 | 8·7957 | 8·8417 | 8·8877 | 8·9334 | 8·9791 | 9·0246 | 9·0700 | 9·1152 | 9·1603 | 9·2052 | ·0454 |
| 61 | 21 9·2501 | 9·2947 | 9·3393 | 9·3837 | 9·4280 | 9·4721 | 9·5161 | 9·5600 | 9·6037 | 9·6473 | ·0441 |
| 62 | 9·6908 | 9·7341 | 9·7773 | 9·8204 | 9·8633 | 9·9062 | 9·9489 | 9·9914 | *0·0338 | *0·0761 | ·0428 |
| 63 | 22 0·1183 | 0·1604 | 0·2023 | 0·2441 | 0·2858 | 0·3273 | 0·3687 | 0·4100 | 0·4512 | 0·4922 | ·0415 |
| 64 | 22 0·5332 | 0·5740 | 0·6147 | 0·6552 | 0·6957 | 0·7360 | 0·7762 | 0·8163 | 0·8563 | 0·8962 | ·0403 |
| 65 | 0·9359 | 0·9755 | 1·0151 | 1·0544 | 1·0937 | 1·1328 | 1·1718 | 1·2107 | 1·2495 | 1·2881 | ·0391 |
| 66 | 1·3267 | 1·3651 | 1·4034 | 1·4416 | 1·4797 | 1·5177 | 1·5555 | 1·5933 | 1·6309 | 1·6684 | ·0379 |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 10 | 1066 | 1238 | 1409 | 1578 | 1745 | 1910 | 2074 | 2236 | 2397 | 2557 | 166 |
| 11 | 2715 | 2871 | 3026 | 3180 | 3333 | 3484 | 3633 | 3782 | 3929 | 4075 | 151 |
| 12 | 4220 | 4363 | 4506 | 4647 | 4787 | 4926 | 5064 | 5200 | 5336 | 5471 | 139 |
| 13 | 5604 | 5737 | 5866 | 5999 | 6129 | 6257 | 6385 | 6511 | 6637 | 6762 | 129 |
| 14 | 6886 | 7009 | 7132 | 7253 | 7373 | 7493 | 7612 | 7730 | 7847 | 7964 | 120 |
| 15 | 8079 | 8194 | 8309 | 8422 | 8535 | 8647 | 8758 | 8868 | 8972 | 9087 | 112 |
| 16 | 9196 | 9304 | 9411 | 9517 | 9623 | 9728 | 9833 | 9937 | 10040 | 10142 | 105 |
| 17 | 10244 | 10346 | 10447 | 10546 | 10645 | 10743 | 10841 | 10939 | 11037 | 11134 | 98 |
| 18 | 11230 | 11326 | 11421 | 11516 | 11610 | 11704 | 11797 | 11890 | 11982 | 12074 | 94 |
| 19 | 12165 | 12256 | 12346 | 12436 | 12525 | 12614 | 12703 | 12791 | 12878 | 12966 | 89 |
| 20 | 13052 | 13139 | 13224 | 13310 | 13395 | 13480 | 13564 | 13648 | 13731 | 13814 | 85 |
| 21 | 13896 | 13979 | 14060 | 14142 | 14223 | 14303 | 14384 | 14463 | 14543 | 14622 | 81 |
| 22 | 14701 | 14779 | 14857 | 14935 | 15013 | 15090 | 15167 | 15244 | 15319 | 15395 | 77 |
| 23 | 15470 | 15545 | 15620 | 15694 | 15768 | 15842 | 15916 | 15989 | 16061 | 16134 | 74 |
| 24 | 16206 | 16278 | 16350 | 16421 | 16492 | 16563 | 16633 | 16703 | 16773 | 16843 | 71 |
| 25 | 1 6912·1 | 6981·2 | 7050·0 | 7118·5 | 7186·7 | 7254·7 | 7322·4 | 7389·8 | 7457·0 | 7523·9 | 68·0 |
| 26 | 7590·6 | 7657·0 | 7723·2 | 7789·1 | 7854·7 | 7920·1 | 7985·3 | 8050·2 | 8114·8 | 8179·3 | 65·4 |
| 27 | 8243·5 | 8307·5 | 8371·2 | 8434·7 | 8498·0 | 8561·0 | 8623·9 | 8686·4 | 8748·8 | 8810·9 | 63·0 |
| 28 | 1 8872·8 | 8934·5 | 8996·0 | 9057·2 | 9118·3 | 9179·1 | 9239·7 | 9300·1 | 9360·3 | 9420·3 | 60·8 |
| 29 | 9480·0 | 9539·6 | 9598·9 | 9658·1 | 9717·0 | 9775·8 | 9834·3 | 9892·6 | 9950·8 | *0008·7 | 58·7 |
| 30 | 2 0066·5 | 0124·0 | 0181·4 | 0238·5 | 0295·5 | 0352·3 | 0409·0 | 0465·4 | 0521·7 | 0577·7 | 56·8 |
| 31 | 2 0633·6 | 0689·3 | 0744·8 | 0800·1 | 0855·3 | 0910·2 | 0965·0 | 1019·6 | 1074·0 | 1128·3 | 55·0 |
| 32 | 1182·4 | 1236·3 | 1290·0 | 1343·5 | 1396·9 | 1450·2 | 1503·2 | 1556·1 | 1608·8 | 1661·4 | 53·2 |
| 33 | 1713·8 | 1766·0 | 1818·1 | 1870·0 | 1921·7 | 1973·3 | 2024·7 | 2076·0 | 2127·1 | 2178·1 | 51·6 |
| 34 | 2 2228·9 | 2279·6 | 2330·0 | 2380·4 | 2430·6 | 2480·6 | 2530·5 | 2580·2 | 2629·7 | 2679·1 | 50·0 |
| 35 | 2728·4 | 2777·5 | 2826·4 | 2875·2 | 2923·8 | 2972·3 | 3020·7 | 3068·8 | 3116·9 | 3164·7 | 48·5 |
| 36 | 3212·5 | 3260·1 | 3307·5 | 3354·8 | 3402·0 | 3449·0 | 3495·9 | 3542·6 | 3589·2 | 3635·6 | 47·0 |
| 37 | 2 3682·0 | 3728·1 | 3774·2 | 3820·0 | 3865·8 | 3911·4 | 3956·9 | 4002·2 | 4047·4 | 4092·5 | 45·6 |
| 38 | 4137·4 | 4182·2 | 4226·8 | 4271·4 | 4315·7 | 4360·0 | 4404·1 | 4448·1 | 4491·9 | 4535·7 | 44·3 |
| 39 | 4579·2 | 4622·7 | 4666·0 | 4709·2 | 4752·3 | 4795·2 | 4838·1 | 4880·8 | 4923·3 | 4965·7 | 42·9 |
| 40 | 2 5008·0 | 5050·2 | 5092·3 | 5134·2 | 5176·0 | 5217·6 | 5259·2 | 5300·6 | 5341·9 | 5383·0 | 41·7 |
| 41 | 5424·0 | 5464·9 | 5505·7 | 5546·4 | 5586·9 | 5627·3 | 5667·6 | 5707·8 | 5747·8 | 5787·8 | 40·4 |
| 42 | 5827·6 | 5867·3 | 5906·9 | 5946·4 | 5985·8 | 6025·0 | 6064·2 | 6103·3 | 6142·2 | 6181·0 | 39·3 |
| 43 | 2 6219·8 | 6258·4 | 6296·9 | 6335·3 | 6373·6 | 6411·8 | 6449·9 | 6487·9 | 6525·8 | 6563·6 | 38·2 |
| 44 | 6601·3 | 6638·9 | 6676·4 | 6713·7 | 6751·0 | 6788·2 | 6825·3 | 6862·3 | 6899·3 | 6936·1 | 37·2 |
| 45 | 6972·8 | 7009·4 | 7046·0 | 7082·4 | 7118·8 | 7155·0 | 7191·2 | 7227·3 | 7263·3 | 7299·2 | 36·3 |
| 46 | 2 7335·1 | 7370·8 | 7406·5 | 7442·1 | 7477·6 | 7513·0 | 7548·3 | 7583·6 | 7618·8 | 7653·9 | 35·4 |
| 47 | 7688·9 | 7723·8 | 7758·7 | 7793·5 | 7828·2 | 7862·8 | 7897·3 | 7931·8 | 7966·2 | 8000·5 | 34·6 |
| 48 | 8034·7 | 8068·9 | 8103·0 | 8137·0 | 8170·9 | 8204·8 | 8238·6 | 8272·3 | 8305·9 | 8339·5 | 33·9 |
| 49 | 2 8373·0 | 8406·5 | 8439·8 | 8473·1 | 8506·4 | 8539·5 | 8572·6 | 8605·6 | 8638·6 | 8671·5 | 33·2 |
| 50 | 8704·3 | 8737·1 | 8769·8 | 8802·4 | 8835·0 | 8867·5 | 8900·0 | 8932·3 | 8964·7 | 8996·9 | 32·5 |
| 51 | 9029·1 | 9061·2 | 9093·2 | 9125·2 | 9157·1 | 9189·0 | 9220·8 | 9252·5 | 9284·2 | 9315·8 | 31·9 |
| 52 | 2 9347·3 | 9378·8 | 9410·3 | 9441·6 | 9472·9 | 9504·2 | 9535·4 | 9566·5 | 9597·6 | 9628·7 | 31·3 |
| 53 | 9659·6 | 9690·6 | 9721·4 | 9752·2 | 9783·0 | 9813·7 | 9844·3 | 9874·9 | 9905·4 | 9935·9 | 30·7 |
| 54 | 9966·3 | 9996·7 | *0027·0 | *0057·3 | *0087·5 | *0117·7 | *0147·8 | *0177·8 | *0207·8 | *0237·8 | 30·2 |
| 55 | 3 0267·6 | 0297·5 | 0327·3 | 0357·0 | 0386·7 | 0416·3 | 0445·9 | 0475·4 | 0504·9 | 0534·3 | 29·6 |
| 56 | 0563·6 | 0592·9 | 0622·2 | 0651·4 | 0680·6 | 0709·7 | 0738·7 | 0767·7 | 0796·7 | 0825·6 | 29·1 |
| 57 | 0854·5 | 0883·3 | 0912·1 | 0940·9 | 0969·6 | 0998·2 | 1026·8 | 1055·4 | 1083·9 | 1112·4 | 28·6 |
| 58 | 3 1140·8 | 1169·2 | 1197·6 | 1226·0 | 1254·3 | 1282·5 | 1310·8 | 1339·0 | 1367·1 | 1395·2 | 28·3 |
| 59 | 1423·3 | 1451·3 | 1479·3 | 1507·3 | 1535·2 | 1563·0 | 1590·9 | 1618·7 | 1646·4 | 1674·2 | 27·9 |
| 60 | 1701·8 | 1729·5 | 1757·1 | 1784·6 | 1812·2 | 1839·6 | 1867·1 | 1894·5 | 1921·9 | 1949·2 | 27·5 |
| 61 | 3 1976·5 | 2003·7 | 2031·0 | 2058·1 | 2085·3 | 2112·4 | 2139·4 | 2166·4 | 2193·4 | 2220·4 | 27·1 |
| 62 | 2247·3 | 2274·2 | 2301·0 | 2327·8 | 2354·5 | 2381·3 | 2407·9 | 2434·6 | 2461·2 | 2487·7 | 26·7 |
| 63 | 2514·3 | 2540·8 | 2567·2 | 2593·6 | 2620·0 | 2646·3 | 2672·6 | 2698·9 | 2725·1 | 2751·3 | 26·3 |
| 64 | 3 2777·5 | 2803·6 | 2829·7 | 2855·7 | 2881·7 | 2907·7 | 2933·7 | 2959·6 | 2985·4 | 3011·2 | 26·0 |
| 65 | 3037·0 | 3062·8 | 3088·5 | 3114·2 | 3139·8 | 3165·4 | 3191·0 | 3216·5 | 3242·0 | 3267·4 | 25·6 |
| 66 | 3292·8 | 3318·2 | 3343·5 | 3368·8 | 3394·1 | 3419·3 | 3444·5 | 3469·6 | 3494·7 | 3519·8 | 25·2 |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 67 | 22 1·7059 | 1·7432 | 1·7804 | 1·8175 | 1·8545 | 1·8914 | 1·9281 | 1·9648 | 2·0014 | 2·0378 | ·0368 |
| 68 | 2·0742 | 2·1105 | 2·1466 | 2·1827 | 2·2186 | 2·2545 | 2·2902 | 2·3259 | 2·3614 | 2·3969 | ·0358 |
| 69 | 2·4322 | 2·4675 | 2·5027 | 2·5377 | 2·5727 | 2·6076 | 2·6424 | 2·6771 | 2·7117 | 2·7462 | ·0348 |
| 70 | 22 2·7806 | 2·8150 | 2·8492 | 2·8833 | 2·9174 | 2·9513 | 2·9852 | 3·0189 | 3·0526 | 3·0862 | ·0339 |
| 71 | 3·1196 | 3·1530 | 3·1863 | 3·2195 | 3·2526 | 3·2856 | 3·3185 | 3·3513 | 3·3840 | 3·4167 | ·0330 |
| 72 | 3·4492 | 3·4816 | 3·5140 | 3·5462 | 3·5784 | 3·6105 | 3·6424 | 3·6743 | 3·7061 | 3·7378 | ·0320 |
| 73 | 22 3·7694 | 3·8009 | 3·8323 | 3·8636 | 3·8949 | 3·9260 | 3·9571 | 3·9881 | 4·0189 | 4·0497 | ·0311 |
| 74 | 4·0804 | 4·1110 | 4·1416 | 4·1720 | 4·2024 | 4·2326 | 4·2628 | 4·2929 | 4·3230 | 4·3529 | ·0302 |
| 75 | 4·3828 | 4·4125 | 4·4422 | 4·4719 | 4·5014 | 4·5398 | 4·5602 | 4·5895 | 4·6187 | 4·6478 | ·0294 |
| 76 | 22 4·6769 | 4·7058 | 4·7347 | 4·7635 | 4·7922 | 4·8208 | 4·8493 | 4·8777 | 4·9060 | 4·9343 | ·0286 |
| 77 | 4·9624 | 4·9905 | 5·0185 | 5·0464 | 5·0742 | 5·1020 | 5·1296 | 5·1572 | 5·1847 | 5·2121 | ·0277 |
| 78 | 5·2394 | 5·2666 | 5·2937 | 5·3208 | 5·3478 | 5·3747 | 5·4015 | 5·4282 | 5·4549 | 5·4814 | ·0268 |
| 79 | 22 5·5079 | 5·5343 | 5·5606 | 5·5869 | 5·6130 | 5·6391 | 5·6652 | 5·6911 | 5·7170 | 5·7428 | ·0261 |
| 80 | 5·7685 | 5·7941 | 5·8197 | 5·8452 | 5·8706 | 5·8959 | 5·9212 | 5·9463 | 5·9714 | 5·9965 | ·0253 |
| 81 | 6·0214 | 6·0463 | 6·0711 | 6·0959 | 6·1205 | 6·1451 | 6·1696 | 6·1941 | 6·2184 | 6·2427 | ·0245 |
| 82 | 22 6·2669 | 6·2910 | 6·3151 | 6·3390 | 6·3629 | 6·3867 | 6·4104 | 6·4340 | 6·4576 | 6·4810 | ·0237 |
| 83 | 6·5044 | 6·5277 | 6·5509 | 6·5740 | 6·5971 | 6·6201 | 6·6430 | 6·6658 | 6·6885 | 6·7111 | ·0229 |
| 84 | 6·7337 | 6·7562 | 6·7786 | 6·8009 | 6·8232 | 6·8454 | 6·8675 | 6·8895 | 6·9114 | 6·9333 | ·0221 |
| 85 | 22 6·9551 | 6·9768 | 6·9984 | 7·0200 | 7·0415 | 7·0629 | 7·0842 | 7·1055 | 7·1267 | 7·1478 | ·0214 |
| 86 | 7·1688 | 7·1898 | 7·2107 | 7·2315 | 7·2522 | 7·2729 | 7·2935 | 7·3140 | 7·3345 | 7·3549 | ·0206 |
| 87 | 7·3752 | 7·3954 | 7·4156 | 7·4357 | 7·4558 | 7·4757 | 7·4956 | 7·5155 | 7·5353 | 7·5550 | ·0199 |
| 88 | 22 7·5746 | 7·5942 | 7·6137 | 7·6332 | 7·6526 | 7·6719 | 7·6912 | 7·7104 | 7·7295 | 7·7486 | ·0193 |
| 89 | 7·7677 | 7·7866 | 7·8055 | 7·8244 | 7·8431 | 7·8618 | 7·8805 | 7·8991 | 7·9176 | 7·9360 | ·0187 |
| 90 | 7·9544 | 7·9727 | 7·9909 | 8·0091 | 8·0272 | 8·0452 | 8·0632 | 8·0812 | 8·0990 | 8·1168 | ·0180 |
| 91 | 22 8·1346 | 8·1523 | 8·1699 | 8·1875 | 8·2050 | 8·2225 | 8·2399 | 8·2573 | 8·2746 | 8·2918 | ·0174 |
| 92 | 8·3090 | 8·3261 | 8·3432 | 8·3602 | 8·3772 | 8·3941 | 8·4109 | 8·4277 | 8·4445 | 8·4611 | ·0169 |
| 93 | 8·4778 | 8·4943 | 8·5109 | 8·5273 | 8·5437 | 8·5601 | 8·5764 | 8·5927 | 8·6089 | 8·6250 | ·0163 |
| 94 | 22 8·6411 | 8·6572 | 8·6732 | 8·6892 | 8·7051 | 8·7209 | 8·7367 | 8·7525 | 8·7682 | 8·7838 | ·0158 |
| 95 | 8·7994 | 8·8150 | 8·8305 | 8·8459 | 8·8613 | 8·8767 | 8·8920 | 8·9073 | 8·9225 | 8·9376 | ·0153 |
| 96 | 8·9528 | 8·9678 | 8·9828 | 8·9978 | 9·0128 | 9·0276 | 9·0425 | 9·0573 | 9·0720 | 9·0867 | ·0149 |
| 97 | 22 9·1014 | 9·1160 | 9·1306 | 9·1451 | 9·1595 | 9·1740 | 9·1884 | 9·2027 | 9·2170 | 9·2312 | ·0144 |
| 98 | 9·2454 | 9·2596 | 9·2737 | 9·2878 | 9·3018 | 9·3158 | 9·3298 | 9·3437 | 9·3575 | 9·3713 | ·0140 |
| 99 | 9·3851 | 9·3989 | 9·4126 | 9·4262 | 9·4398 | 9·4534 | 9·4670 | 9·4805 | 9·4939 | 9·5073 | ·0136 |
| 100 | 22 9·5207 | 9·5340 | 9·5473 | 9·5606 | 9·5738 | 9·5869 | 9·6001 | 9·6132 | 9·6262 | 9·6392 | ·0132 |
| 101 | 9·6522 | 9·6651 | 9·6780 | 9·6908 | 9·7036 | 9·7164 | 9·7291 | 9·7418 | 9·7544 | 9·7670 | ·0127 |
| 102 | 9·7796 | 9·7921 | 9·8046 | 9·8170 | 9·8294 | 9.8417 | 9·8540 | 9·8662 | 9·8783 | 9·8904 | ·0123 |
| 103 | 22 9·9024 | 9·9144 | 9·9262 | 9·9380 | 9·9496 | 9·9612 | 9·9727 | 9·9841 | 9·9954 | *0·0066 | ·0115 |
| 104 | 23 0·0177 | 0·0287 | 0·0396 | 0·0504 | 0·0610 | 0·0716 | 0·0820 | 0·0923 | 0·1025 | 0·1126 | ·0105 |
| 105 | 0·1226 | 0·1325 | 0·1423 | 0·1520 | 0·1615 | 0·1710 | 0·1804 | 0·1897 | 0·1988 | 0·2079 | ·0094 |
| 106 | 23 0·2170 | 0·2259 | 0·2347 | 0·2435 | 0·2522 | 0·2609 | 0·2694 | 0·2780 | 0·2864 | 0·2948 | ·0086 |
| 107 | 0·3031 | 0·3114 | 0·3196 | 0·3278 | 0·3359 | 0·3439 | 0·3520 | 0·3599 | 0·3678 | 0·3757 | ·0080 |
| 108 | 0·3835 | 0·3913 | 0·3990 | 0·4067 | 0·4143 | 0·4219 | 0·4295 | 0·4370 | 0·4445 | 0·4519 | ·0076 |
| 109 | 23 0·4593 | 0·4667 | 0·4740 | 0·4813 | 0·4885 | 0·4958 | 0·5030 | 0·5101 | 0·5172 | 0·5243 | ·0072 |
| 110 | 0·5314 | 0·5384 | 0·5454 | 0·5524 | 0·5593 | 0·5662 | 0·5731 | 0·5800 | 0·5868 | 0·5936 | ·0069 |
| 111 | 0·6004 | 0·6071 | 0·6139 | 0·6206 | 0·6272 | 0·6339 | 0·6405 | 0·6471 | 0·6537 | 0·6603 | ·0066 |
| 112 | 23 0·6668 | 0·6733 | 0·6798 | 0·6863 | 0·6928 | 0·6992 | 0·7056 | 0·7120 | 0·7184 | 0·7248 | ·0064 |
| 113 | 0·7311 | 0·7374 | 0·7437 | 0·7500 | 0·7563 | 0·7625 | 0·7688 | 0·7750 | 0·7812 | 0·7874 | ·0062 |
| 114 | 0·7936 | 0·7997 | 0·8059 | 0·8120 | 0·8181 | 0·8242 | 0·8303 | 0·8364 | 0·8424 | 0·8484 | ·0061 |
| 115 | 23 0·8545 | 0·8605 | 0·8665 | 0·8726 | 0·8787 | 0·8847 | 0·8906 | 0·8965 | 0·9024 | 0·9083 | ·0059 |
| 116 | 0·3142 | 0·9200 | 0·9259 | 0·9317 | 0·9375 | 0·9433 | 0·9490 | 0·9548 | 0·9605 | 0·9663 | ·0058 |
| 117 | 0·9720 | 0·9777 | 0·9833 | 0·9890 | 0·9947 | 1·0003 | 1·0059 | 1·0115 | 1·0171 | 1·0227 | ·0056 |
| 118 | 23 1·0283 | 1·0338 | 1·0394 | 1·0449 | 1·0504 | 1·0559 | 1·0614 | 1·0669 | 1·0723 | 1·0778 | ·0055 |
| 119 | 1·0832 | 1·0886 | 1·0940 | 1·0994 | 1·1048 | 1·1101 | 1·1154 | 1·1208 | 1·1261 | 1·1314 | ·0054 |
| 120 | 1·1367 | 1·1420 | 1·1473 | 1·1525 | 1·1578 | 1·1630 | 1·1682 | 1·1734 | 1·1786 | 1·1838 | ·0052 |
| 121 | 23 1·1889 | 1·1941 | 1·1992 | 1·2043 | 1·2095 | 1·2146 | 1·2196 | 1·2247 | 1·2298 | 1·2348 | ·0051 |
| 122 | 1·2399 | 1·2449 | 1·2499 | 1·2549 | 1·2599 | 1·2649 | 1·2698 | 1·2748 | 1·2797 | 1·2847 | ·0050 |
| 123 | 1·2896 | 1·2945 | 1·2994 | 1·3043 | 1·3091 | 1·3140 | 1·3188 | 1·3237 | 1·3285 | 1·3333 | 0049 |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 67 | 3 3544·8 | 3569·8 | 3594·8 | 3619·8 | 3644.7 | 3669·5 | 3694·3 | 3719·1 | 3743·9 | 3768·6 | 24·8 |
| 68 | 3793·3 | 3818·0 | 3842·6 | 3867·2 | 3891·7 | 3916·2 | 3940·7 | 3965·2 | 3989·6 | 4014·0 | 24·5 |
| 69 | 4038·4 | 4062·7 | 4087·0 | 4111·3 | 4135·6 | 4159·8 | 4184·0 | 4208·1 | 4232·2 | 4256·3 | 24·2 |
| 70 | 3 4280·4 | 4304·5 | 4328·5 | 4352·4 | 4376·4 | 4400·3 | 4424·1 | 4448·0 | 4471·8 | 4495·5 | 23·9 |
| 71 | 4519·3 | 4543·0 | 4566·6 | 4590·2 | 4613·8 | 4637·4 | 4660·9 | 4684·4 | 4707·8 | 4731·3 | 23·5 |
| 72 | 4754·7 | 4777·9 | 4801·3 | 4824·6 | 4847·9 | 4871·1 | 4894·2 | 4917·4 | 4940·5 | 4963·6 | 23·2 |
| 73 | 3 4986·6 | 5009·6 | 5032·6 | 5055·5 | 5078·4 | 5101·3 | 5124·1 | 5146·9 | 5169·6 | 5192·4 | 22·8 |
| 74 | 5215·1 | 5237·7 | 5260·3 | 5282·9 | 5305·5 | 5328·0 | 5350·5 | 5373·0 | 5395·4 | 5417·8 | 22·5 |
| 75 | 5440·2 | 5462·5 | 5484·8 | 5507·1 | 5529·3 | 5551·5 | 5573·7 | 5595·8 | 5617·9 | 5640·0 | 22·2 |
| 76 | 3 5662·1 | 5684·1 | 5706·0 | 5728·0 | 5749·9 | 5771·7 | 5793·5 | 5815·3 | 5837·0 | 5858·7 | 21·8 |
| 77 | 5880·4 | 5902·0 | 5923·6 | 5945·1 | 5966·6 | 5988·1 | 6009·5 | 6030·9 | 6052·2 | 6073·6 | 21·5 |
| 78 | 6094·8 | 6116·1 | 6137·3 | 6158·4 | 6179·6 | 6200·7 | 6221·7 | 6242·7 | 6263·7 | 6284·6 | 21·1 |
| 79 | 3 6305·5 | 6326·4 | 6347·2 | 6368·0 | 6388·8 | 6409·5 | 6430·2 | 6450·8 | 6471·4 | 6492·0 | 20·7 |
| 80 | 6512·6 | 6533·1 | 6553·6 | 6574·0 | 6594·4 | 6614·8 | 6635·1 | 6655·4 | 6675·7 | 6695·9 | 20·4 |
| 81 | 6716·1 | 6736·3 | 6756·4 | 6776·5 | 6796·5 | 6816·5 | 6836·5 | 6856·4 | 6876·3 | 6896·1 | 20·0 |
| 82 | 3 6916·0 | 6935·7 | 6955·5 | 6975·1 | 6994·8 | 7014·4 | 7033·9 | 7053·4 | 7072·9 | 7092·3 | 19·6 |
| 83 | 7111·7 | 7131·0 | 7150·3 | 7169·6 | 7188·8 | 7207·9 | 7227·1 | 7246·1 | 7265·2 | 7284·1 | 19·1 |
| 84 | 7303·1 | 7322·0 | 7340·8 | 7359·6 | 7378·4 | 7397·1 | 7415·8 | 7434·4 | 7453·0 | 7471·5 | 18·7 |
| 85 | 3 7490·0 | 7508·5 | 7526·9 | 7545·3 | 7563·6 | 7581·8 | 7600·0 | 7618·2 | 7636·3 | 7654·4 | 18·2 |
| 86 | 7672·4 | 7690·5 | 7708·4 | 7726·4 | 7744·2 | 7762·0 | 7779·9 | 7797·6 | 7815·4 | 7833·0 | 17·8 |
| 87 | 7850·6 | 7868·2 | 7885·8 | 7903·3 | 7920·8 | 7938·2 | 7955·6 | 7973·0 | 7990·3 | 8007·6 | 17·4 |
| 88 | 3 8024·8 | 8042·0 | 8059·2 | 8076·3 | 8093·4 | 8110·4 | 8127·4 | 8144·4 | 8161·3 | 8178·2 | 17·0 |
| 89 | 8195·0 | 8211·9 | 8228·6 | 8245·4 | 8262·1 | 8278·7 | 8295·4 | 8312·0 | 8328·5 | 8345·0 | 16·6 |
| 90 | 8361·5 | 8377·9 | 8394·3 | 8410·7 | 8427·0 | 8443·3 | 8459·6 | 8475·8 | 8492·0 | 8508·2 | 16·3 |
| 91 | 3 8524·3 | 8540·4 | 8556·4 | 8572·4 | 8588·4 | 8604·3 | 8620·3 | 8636·1 | 8652·0 | 8667·8 | 15·9 |
| 92 | 8683·5 | 8699·3 | 8715·0 | 8730·7 | 8746·3 | 8761·9 | 8777·5 | 8793·0 | 8808·5 | 8824·0 | 15·6 |
| 93 | 8839·4 | 8854·8 | 8870·2 | 8885·5 | 8900·8 | 8916·1 | 8931·3 | 8946·5 | 8961·7 | 8976·8 | 15·3 |
| 94 | 3 8991·9 | 9007·0 | 9022·0 | 9037·0 | 9052·9 | 9066·9 | 9081·9 | 9096·7 | 9111·6 | 9126·4 | 15·0 |
| 95 | 9141·2 | 9156·0 | 9170·7 | 9185·4 | 9200·1 | 9214·7 | 9229·3 | 9243·9 | 9258·4 | 9272·9 | 14·6 |
| 96 | 9287·4 | 9301·9 | 9316·3 | 9330·7 | 9345·0 | 9359·4 | 9373·7 | 9387·9 | 9402·2 | 9416·4 | 14·3 |
| 97 | 3 9430·6 | 9444·7 | 9458·9 | 9473·0 | 9487·0 | 9501·1 | 9515·1 | 9529·1 | 9543·0 | 9557·0 | 14·0 |
| 98 | 9570·8 | 9584·7 | 9598·6 | 9612·4 | 9626·1 | 9639·9 | 9653·6 | 9667·3 | 9681·0 | 9694·6 | 13·7 |
| 99 | 9708·3 | 9721·9 | 9735·4 | 9749·0 | 9762·5 | 9775·9 | 9789·4 | 9802·8 | 9816·2 | 9829·6 | 13·5 |
| 100 | 3 9842·9 | 9856·3 | 9869·6 | 9882·9 | 9896·1 | 9909·3 | 9922·5 | 9935·7 | 9948·8 | 9961·9 | 13·2 |
| 101 | 9975·0 | 9988·1 | *0001·1 | *0014·1 | *0027·1 | *0040·0 | *0052·9 | *0065·8 | *0078·7 | *0091·5 | 12·9 |
| 102 | 4 0104·3 | 0117·1 | 0129·8 | 0142·5 | 0155·2 | 0167·8 | 0180·4 | 0192·9 | 0205·4 | 0217·8 | 12·6 |
| 103 | 4 0230·1 | 0242·4 | 0254·6 | 0266·8 | 0278·8 | 0290·8 | 0302·7 | 0314·5 | 0326·2 | 0337·8 | 11·9 |
| 104 | 0349·4 | 0360·8 | 0372·2 | 0383·4 | 0394·5 | 0405·6 | 0416·5 | 0427·3 | 0438·1 | 0448·7 | 11·0 |
| 105 | 0459·2 | 0469·6 | 0479·9 | 0490·0 | 0500·1 | 0510·1 | 0520·0 | 0529·8 | 0539·5 | 0549·2 | 9·9 |
| 106 | 4 0558·7 | 0568·2 | 0577·6 | 0586·9 | 0596·2 | 0605·4 | 0614·5 | 0623·6 | 0632·6 | 0641·6 | 9·2 |
| 107 | 0650·5 | 0659·3 | 0668·1 | 0676·9 | 0685·6 | 0694·2 | 0702·8 | 0711·4 | 0719·9 | 0728·4 | 8·6 |
| 108 | 0736·8 | 0745·2 | 0753·6 | 0761·9 | 0770·2 | 0778·4 | 0786·6 | 0794·8 | 0802·9 | 0811·0 | 8·2 |
| 109 | 4 0819·0 | 0827·1 | 0835·0 | 0843·0 | 0850·9 | 0858·9 | 0866·7 | 0874·6 | 0882·4 | 0890·2 | 7·9 |
| 110 | 0897·9 | 0905·7 | 0913·4 | 0921·1 | 0928·7 | 0936·4 | 0944·0 | 0951·5 | 0959·1 | 0966·6 | 7·6 |
| 111 | 0974·2 | 0981·6 | 0989·1 | 0996·6 | 1004·0 | 1011·4 | 1018·8 | 1026·2 | 1033·5 | 1040·9 | 7·4 |
| 112 | 4 1048·2 | 1055·5 | 1062·8 | 1070·0 | 1077·3 | 1084·5 | 1091·7 | 1099·0 | 1106·1 | 1113·3 | 7·2 |
| 113 | 1120·5 | 1127·6 | 1134·8 | 1141·9 | 1149·0 | 1156·1 | 1163·2 | 1170·2 | 1177·3 | 1184·4 | 7·1 |
| 114 | 1191·4 | 1198·4 | 1205·4 | 1212·4 | 1219·4 | 1226·4 | 1233·3 | 1240·3 | 1247·2 | 1254·1 | 6·9 |
| 115 | 4 1261·0 | 1267·9 | 1274·8 | 1281·7 | 1288·6 | 1295·4 | 1302·3 | 1309·1 | 1315·9 | 1322·7 | 6·8 |
| 116 | 1329·5 | 1336·3 | 1343·1 | 1349·8 | 1356·6 | 1363·3 | 1370·0 | 1376·7 | 1383·4 | 1390·1 | 6·7 |
| 117 | 1396·8 | 1403·5 | 1410·1 | 1416·8 | 1423·4 | 1430·0 | 1436·6 | 1443·2 | 1449·8 | 1456·4 | 6·6 |
| 118 | 4 1462·9 | 1469·5 | 1476·0 | 1482·6 | 1489·1 | 1495·6 | 1502·1 | 1508·6 | 1515·1 | 1521·5 | 6·5 |
| 119 | 1528·0 | 1534·4 | 1540·9 | 1547·3 | 1553·7 | 1560·1 | 1566·5 | 1572·9 | 1579·2 | 1585·6 | 6·4 |
| 120 | 1591·9 | 1598·3 | 1604·6 | 1610·9 | 1617·2 | 1623·5 | 1629·8 | 1636·1 | 1642·3 | 1648·6 | 6·3 |
| 121 | 4 1654·8 | 1661·1 | 1667·3 | 1673·5 | 1679·7 | 1685·9 | 1692·1 | 1698·2 | 1704·4 | 1710·5 | 6·2 |
| 122 | 1716·7 | 1722·8 | 1728·9 | 1735·0 | 1741·1 | 1747·2 | 1753·3 | 1759·4 | 1765·4 | 1771·5 | 6·1 |
| 123 | 1777·5 | 1783·6 | 1789·6 | 1795·6 | 1801·6 | 1807·6 | 1813·6 | 1819·6 | 1825·6 | 1831·5 | 6·0 |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 124 | 23 1·3381 | 1·3429 | 1·3477 | 1·3524 | 1·3572 | 1·3619 | 1·3667 | 1·3714 | 1·3761 | 1·3808 | ·0047 |
| 125 | 1·3855 | 1·3902 | 1·3948 | 1·3995 | 1·4041 | 1·4088 | 1·4134 | 1·4180 | 1·4226 | 1·4272 | ·0046 |
| 126 | 1·4318 | 1·4364 | 1·4410 | 1.4455 | 1·4501 | 1·4546 | 1·4591 | 1·4636 | 1·4681 | 1·4726 | ·0045 |
| 127 | 23 1·4771 | 1·4816 | 1·4860 | 1·4905 | 1·4949 | 1·4993 | 1·5038 | 1·5082 | 1·5126 | 1·5170 | ·0044 |
| 128 | 1·5214 | 1·5257 | 1·5301 | 1·5345 | 1·5388 | 1·5431 | 1·5475 | 1·5518 | 1·5561 | 1·5604 | ·0043 |
| 129 | 1·5647 | 1·5690 | 1·5732 | 1·5775 | 1·5818 | 1·5860 | 1·5902 | 1·5945 | 1·5987 | 1·6029 | ·0042 |
| 130 | 23 1·6071 | 1·6113 | 1·6155 | 1·6196 | 1·6238 | 1·6280 | 1·6321 | 1·6362 | 1·6404 | 1·6445 | ·0042 |
| 131 | 1·6486 | 1·6527 | 1·6568 | 1·6609 | 1·6650 | 1·6690 | 1·6731 | 1·6772 | 1·6812 | 1·6852 | ·0041 |
| 132 | 1·6893 | 1·6933 | 1·6973 | 1·7013 | 1·7053 | 1·7093 | 1·7133 | 1·7173 | 1·7212 | 1·7252 | ·0040 |
| 133 | 23 1·7291 | 1·7331 | 1·7370 | 1·7410 | 1·7449 | 1·7488 | 1·7527 | 1·7566 | 1·7605 | 1·7644 | ·0039 |
| 134 | 1·7682 | 1·7721 | 1·7760 | 1·7798 | 1·7837 | 1·7875 | 1·7913 | 1·7952 | 1·7990 | 1·8028 | ·0038 |
| 135 | 1·8066 | 1·8104 | 1·8142 | 1·8179 | 1·8217 | 1·8255 | 1·8292 | 1·8330 | 1·8367 | 1·8405 | ·0038 |
| 136 | 23 1·8442 | 1·8479 | 1·8517 | 1·8554 | 1·8591 | 1·8628 | 1·8665 | 1·8702 | 1·8738 | 1·8775 | ·0037 |
| 137 | 1·8812 | 1·8848 | 1·8885 | 1·8921 | 1·8958 | 1·8994 | 1·9030 | 1·9067 | 1·9103 | 1·9139 | ·0036 |
| 138 | 1·9175 | 1·9211 | 1·9247 | 1·9282 | 1·9318 | 1·9354 | 1·9390 | 1·9425 | 1·9461 | 1·9496 | ·0036 |
| 139 | 23 1·9532 | 1·9567 | 1·9602 | 1·9638 | 1·9673 | 1·9708 | 1·9743 | 1·9778 | 1·9813 | 1·9848 | ·0035 |
| 140 | 1·9883 | 1·9918 | 1·9952 | 1·9987 | 2·0022 | 2·0056 | 2·0091 | 2·0125 | 2·0160 | 2·0194 | ·0035 |
| 141 | 2·0228 | 2·0263 | 2·0297 | 2·0331 | 2·0365 | 2·0399 | 2·0433 | 2·0467 | 2·0501 | 2·0535 | ·0034 |
| 142 | 23 2·0569 | 2·0602 | 2·0636 | 2·0670 | 2·0703 | 2·0737 | 2·0770 | 2·0804 | 2·0837 | 2·0870 | ·0034 |
| 143 | 2·0904 | 2·0937 | 2·0970 | 2·1003 | 2·1036 | 2·1069 | 2·1102 | 2·1135 | 2·1168 | 2·1201 | ·0033 |
| 144 | 2·1234 | 2·1267 | 2·1299 | 2·1332 | 2·1364 | 2·1397 | 2·1430 | 2·1462 | 2·1494 | 2·1527 | ·0033 |
| 145 | 23 2·1559 | 2·1591 | 2·1624 | 2·1656 | 2·1688 | 2·1720 | 2·1752 | 2·1784 | 2·1816 | 2·1848 | ·0032 |
| 146 | 2·1880 | 2·1912 | 2·1944 | 2·1975 | 2·2007 | 2·2039 | 2·2071 | 2·2102 | 2·2134 | 2·2165 | ·0032 |
| 147 | 2·2197 | 2·2228 | 2·2260 | 2·2291 | 2·2322 | 2·2354 | 2·2385 | 2·2416 | 2·2447 | 2·2478 | ·0031 |
| 148 | 23 2·2509 | 2·2540 | 2·2571 | 2·2602 | 2·2633 | 2·2664 | 2·2695 | 2·2726 | 2·2757 | 2·2787 | ·0031 |
| 149 | 2·2818 | 2·2849 | 2·2879 | 2·2910 | 2·2940 | 2·2971 | 2·3001 | 2·3032 | 2·3062 | 2·3093 | ·0030 |
| 150 | 2·3123 | 2·3153 | 2·3183 | 2·3214 | 2·3244 | 2·3274 | 2·3304 | 2·3334 | 2·3364 | 2·3394 | ·0030 |
| 151 | 23 2·3424 | 2·3454 | 2·3484 | 2·3514 | 2·3543 | 2·3573 | 2·3603 | 2·3633 | 2·3662 | 2·3692 | ·0030 |
| 152 | 2·3722 | 2·3751 | 2·3781 | 2·3810 | 2·3840 | 2·3869 | 2·3899 | 2·3928 | 2·3958 | 2·3987 | ·0029 |
| 153 | 2·4016 | 2·4046 | 2·4075 | 2·4104 | 2·4133 | 2·4162 | 2·4192 | 2·4221 | 2·4250 | 2·4279 | ·0029 |
| 154 | 23 2·4308 | 2·4337 | 2·4366 | 2·4395 | 2·4424 | 2·4453 | 2·4481 | 2·4510 | 2·4539 | 2·4568 | ·0029 |
| 155 | 2·4597 | 2·4625 | 2·4654 | 2·4683 | 2·4711 | 2·4740 | 2·4768 | 2·4797 | 2·4825 | 2·4854 | ·0029 |
| 156 | 2·4882 | 2·4911 | 2·4939 | 2·4967 | 2·4996 | 2·5024 | 2·5052 | 2·5080 | 2·5108 | 2·5137 | ·0028 |
| 157 | 23 2·5165 | 2·5193 | 2·5221 | 2·5249 | 2·5277 | 2·5305 | 2·5333 | 2·5361 | 2·5389 | 2·5416 | ·0028 |
| 158 | 2·5444 | 2·5472 | 2·5500 | 2·5528 | 2·5555 | 2·5583 | 2·5611 | 2·5638 | 2·5666 | 2·5693 | ·0028 |
| 159 | 2·5721 | 2·5748 | 2·5776 | 2·5803 | 2·5831 | 2·5858 | 2·5885 | 2·5913 | 2·5940 | 2·5967 | ·0027 |
| 160 | 23 2·5994 | 2·6022 | 2·6049 | 2·6076 | 2·6103 | 2·6130 | 2·6157 | 2·6184 | 2·6211 | 2·6238 | ·0027 |
| 161 | 2·6265 | 2·6292 | 2·6319 | 2·6346 | 2·6373 | 2·6400 | 2·6426 | 2·6453 | 2·6480 | 2·6506 | ·0027 |
| 162 | 2·6533 | 2·6560 | 2·6586 | 2·6613 | 2·6640 | 2·6666 | 2·6693 | 2·6719 | 2·6745 | 2·6772 | ·0026 |
| 163 | 23 2·6798 | 2·6825 | 2·6851 | 2·6877 | 2·6903 | 2·6930 | 2·6956 | 2·6982 | 2·7008 | 2·7034 | ·0026 |
| 164 | 2·7061 | 2·7087 | 2·7113 | 2·7139 | 2·7165 | 2·7191 | 2·7217 | 2·7243 | 2·7268 | 2·7294 | ·0026 |
| 165 | 2·7320 | 2·7346 | 2·7372 | 2·7398 | 2·7423 | 2·7449 | 2·7475 | 2·7500 | 2·7526 | 2·7552 | ·0026 |
| 166 | 23 2·7577 | 2·7603 | 2·7628 | 2·7654 | 2·7679 | 2·7705 | 2·7730 | 2·7756 | 2·7781 | 2·7806 | ·0025 |
| 167 | 2·7832 | 2·7857 | 2·7882 | 2·7908 | 2·7933 | 2·7958 | 2·7983 | 2·8008 | 2·8034 | 2·8059 | ·0025 |
| 168 | 2·8084 | 2·8109 | 2·8134 | 2·8159 | 2·8184 | 2·8209 | 2·8234 | 2·8258 | 2·8283 | 2·8308 | ·0025 |
| 169 | 23 2·8333 | 2·8358 | 2·8383 | 2·8407 | 2·8432 | 2·8457 | 2·8481 | 2·8506 | 2·8531 | 2·8555 | ·0025 |
| 170 | 2·8580 | 2·8604 | 2·8629 | 2·8653 | 2·8678 | 2·8702 | 2·8726 | 2·8751 | 2·8775 | 2·8799 | ·0024 |
| 171 | 2·8824 | 2·8848 | 2·8872 | 2·8896 | 2·8921 | 2·8945 | 2·8969 | 2·8993 | 2·9017 | 2·9041 | ·0024 |
| 172 | 23 2·9065 | 2·9089 | 2·9113 | 2·9137 | 2·9161 | 2·9185 | 2·9209 | 2·9233 | 2·9257 | 2·9281 | ·0024 |
| 173 | 2·9304 | 2·9328 | 2·9352 | 2·9376 | 2·9399 | 2·9423 | 2·9447 | 2·9470 | 2·9494 | 2·9518 | ·0024 |
| 174 | 2·9541 | 2·9565 | 2·9588 | 2·9612 | 2·9635 | 2·9659 | 2·9682 | 2·9705 | 2·9729 | 2·9752 | ·0023 |
| 175 | 23 2·9776 | 2·9799 | 2·9822 | 2·9845 | 2·9869 | 2·9892 | 2·9915 | 2·9938 | 2·9961 | 2·9985 | ·0023 |
| 176 | 3·0008 | 3·0031 | 3·0054 | 3·0077 | 3·0100 | 3·0123 | 3·0146 | 3·0169 | 3·0192 | 3·0215 | ·0023 |
| 177 | 3·0237 | 3·0260 | 3·0283 | 3·0306 | 3·0329 | 3·0351 | 3·0374 | 3·0397 | 3·0420 | 3·0442 | ·0023 |
| 178 | 23 3·0465 | 3·0488 | 3·0510 | 3·0533 | 3·0555 | 3·0578 | 3·0600 | 3·0623 | 3·0645 | 3·0668 | ·0023 |
| 179 | 3·0690 | 3·0713 | 3·0735 | 3·0757 | 3·0780 | 3·0802 | 3·0824 | 3·0847 | 3·0869 | 3·0891 | ·0022 |
| 180 | 3·0913 | 3·0935 | 3·0958 | 3·0980 | 3·1002 | 3·1024 | 3·1045 | 3·1068 | 3·1090 | 3·1112 | ·0022 |

| $v$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 124 | 4 1837·5 | 1843·4 | 1849·4 | 1855·3 | 1861.2 | 1867·1 | 1873·0 | 1878·9 | 1884·8 | 1890·6 | 5·9 |
| 125 | 1896·5 | 1902·3 | 1908·2 | 1914·0 | 1919·8 | 1925·6 | 1931·5 | 1937·3 | 1943·0 | 1948·8 | 5·8 |
| 126 | 1954·6 | 1960·4 | 1966·1 | 1971·9 | 1977·6 | 1983·3 | 1989·0 | 1994·8 | 2000·5 | 2006·2 | 5·7 |
| 127 | 4 2011·8 | 2017·5 | 2023·2 | 2028·9 | 2034·5 | 2040·2 | 2045·8 | 2051·4 | 2057·0 | 2062·7 | 5·6 |
| 128 | 2068·3 | 2073·9 | 2079·5 | 2085·0 | 2090·6 | 2096·2 | 2101·8 | 2107·3 | 2112·9 | 2118·4 | 5·6 |
| 129 | 2123·9 | 2129·4 | 2135·0 | 2140·5 | 2146·0 | 2151·5 | 2157·0 | 2162·4 | 2167·9 | 2173·4 | 5·5 |
| 130 | 4 2178·8 | 2184·3 | 2189·7 | 2195·1 | 2200·6 | 2206·0 | 2211·4 | 2216·8 | 2222·2 | 2227·6 | 5·4 |
| 131 | 2233·0 | 2238·4 | 2243·7 | 2249·1 | 2254·5 | 2259·8 | 2265·1 | 2270·5 | 2275·8 | 2281·1 | 5·3 |
| 132 | 2286·4 | 2291·8 | 2297·1 | 2302·4 | 2307·6 | 2312·9 | 2318·2 | 2323·5 | 2328·7 | 2334·0 | 5·3 |
| 133 | 4 2339·2 | 2344·5 | 2349·7 | 2355·0 | 2360·2 | 2365·4 | 2370·6 | 2375·8 | 2381·0 | 2386·2 | 5·2 |
| 134 | 2391·4 | 2396·6 | 2401·8 | 2406·9 | 2412·1 | 2417·3 | 2422·4 | 2427·6 | 2432·7 | 2437·8 | 5·2 |
| 135 | 2443·0 | 2448·1 | 2453·2 | 2458·3 | 2463·4 | 2468·5 | 2473·6 | 2478·7 | 2483·8 | 2488·9 | 5·1 |
| 136 | 4 2493·9 | 2499·0 | 2504·1 | 2509·1 | 2514·2 | 2519·2 | 2524·3 | 2529·3 | 2534·3 | 2539·4 | 5·0 |
| 137 | 2544·4 | 2549·4 | 2554·4 | 2559·4 | 2564·4 | 2569·4 | 2574·4 | 2579·4 | 2584·3 | 2589·3 | 5·0 |
| 138 | 2594·3 | 2599·2 | 2604·2 | 2609·1 | 2614·1 | 2619·0 | 2624·0 | 2628·9 | 2633·8 | 2638·8 | 4·9 |
| 139 | 4 2643·7 | 2648·6 | 2653·5 | 2658·4 | 2663·3 | 2668·2 | 2673·1 | 2678·0 | 2682·9 | 2687·8 | 4·9 |
| 140 | 2692·6 | 2697·5 | 2702·4 | 2707·2 | 2712·1 | 2717·0 | 2721·8 | 2726·7 | 2731·5 | 2736·3 | 4·9 |
| 141 | 2741·2 | 2746·0 | 2750·8 | 2755·7 | 2760·5 | 2765·3 | 2770·1 | 2774·9 | 2779·7 | 2784·5 | 4·8 |
| 142 | 4 2789·3 | 2794·1 | 2798·9 | 2803·7 | 2808·5 | 2813·2 | 2818·0 | 2822·8 | 2827·5 | 2832·3 | 4·8 |
| 143 | 2837·1 | 2841·8 | 2846·6 | 2851·3 | 2856·0 | 2860·8 | 2865·5 | 2870·2 | 2875·0 | 2879·7 | 4·7 |
| 144 | 2884·4 | 2889·1 | 2893·8 | 2898·6 | 2903·3 | 2908·0 | 2912·7 | 2917·4 | 2922·1 | 2926·7 | 4·7 |
| 145 | 4 2931·4 | 2936·1 | 2940·8 | 2945·5 | 2950·1 | 2954·8 | 2959·5 | 2964·1 | 2968·8 | 2973·5 | 4·7 |
| 146 | 2978·1 | 2982·8 | 2987·4 | 2992·1 | 2996·7 | 3001·3 | 3006·0 | 3010·6 | 3015·2 | 3019·9 | 4·6 |
| 147 | 3024·5 | 3029·1 | 3033·7 | 3038·4 | 3043·0 | 3047·6 | 3052·2 | 3056·8 | 3061·4 | 3066·0 | 4·6 |
| 148 | 4 3070·6 | 3075·2 | 3079·8 | 3084·4 | 3089·0 | 3093·5 | 3098·1 | 3102·7 | 3107·3 | 3111·8 | 4·6 |
| 149 | 3116·4 | 3121·0 | 3125·6 | 3130·1 | 3134·7 | 3139·2 | 3143·8 | 3148·3 | 3152·9 | 3157·4 | 4·6 |
| 150 | 3162·0 | 3166·5 | 3171·0 | 3175·6 | 3180·1 | 3184·6 | 3189·2 | 3193·7 | 3198·2 | 3202·7 | 4·5 |
| 151 | 4 3207·2 | 3211·8 | 3216·3 | 3220·8 | 3225·3 | 3229·8 | 3234·3 | 3238·8 | 3243·3 | 3247·8 | 4·5 |
| 152 | 3252·3 | 3256·8 | 3261·3 | 3265·8 | 3270·3 | 3274·8 | 3279·3 | 3283·8 | 3288·3 | 3292·8 | 4·5 |
| 153 | 3297·2 | 3301·7 | 3306·2 | 3310·6 | 3315·1 | 3319·6 | 3324·1 | 3328·5 | 3333·0 | 3337·5 | 4·5 |
| 154 | 4 3342·0 | 3346·4 | 3350·9 | 3355·3 | 3359·8 | 3364·3 | 3368·7 | 3373·2 | 3377·6 | 3382·1 | 4·5 |
| 155 | 3386·5 | 3391·0 | 3395·4 | 3399·9 | 3404·3 | 3408·7 | 3413·2 | 3417·6 | 3422·0 | 3426·5 | 4·4 |
| 156 | 3430·9 | 3435·3 | 3439·8 | 3444·2 | 3448·6 | 3453·0 | 3457·4 | 3461·9 | 3466·3 | 3470·7 | 4·4 |
| 157 | 4 3475·1 | 3479·5 | 3483·9 | 3488·3 | 3492·7 | 3497·1 | 3501·5 | 3505·9 | 3510·3 | 3514·7 | 4·4 |
| 158 | 3519·1 | 3523·5 | 3527·9 | 3532·3 | 3536·7 | 3541·1 | 3545·4 | 3549·8 | 3554·2 | 3558·6 | 4·4 |
| 159 | 3563·0 | 3567·3 | 3571·7 | 3576·1 | 3580·4 | 3584·8 | 3589·1 | 3593·5 | 3597·9 | 3602·2 | 4·4 |
| 160 | 4 3606·6 | 3610·9 | 3615·3 | 3619·6 | 3624·0 | 3628·3 | 3632·6 | 3637·0 | 3641·3 | 3645·7 | 4·3 |
| 161 | 3650·0 | 3654·3 | 3658·7 | 3663·0 | 3667·3 | 3671·6 | 3676·0 | 3680·3 | 3684·6 | 3688·9 | 4·3 |
| 162 | 3693·3 | 3697·6 | 3701·9 | 3706·1 | 3710·5 | 3714·8 | 3719·1 | 3723·4 | 3727·7 | 3732·0 | 4·3 |
| 163 | 4 3736·3 | 3740·6 | 3744·9 | 3749·2 | 3753·5 | 3757·8 | 3762·1 | 3766·4 | 3770·6 | 3774·9 | 4·3 |
| 164 | 3779·2 | 3783·5 | 3787·8 | 3792·0 | 3796·3 | 3800·6 | 3804·9 | 3809·1 | 3813·4 | 3817·6 | 4·3 |
| 165 | 3821·9 | 3826·2 | 3830·4 | 3834·7 | 3838·9 | 3843·2 | 3847·4 | 3851·7 | 3855·9 | 3860·2 | 4·3 |
| 166 | 4 3864·4 | 3868·7 | 3872·9 | 3877·2 | 3881·4 | 3885·6 | 3889·9 | 3894·1 | 3898·3 | 3902·5 | 4·2 |
| 167 | 3906·8 | 3911·0 | 3915·2 | 3919·5 | 3923·7 | 3927·9 | 3932·1 | 3936·3 | 3940·5 | 3944·7 | 4·2 |
| 168 | 3949·0 | 3953·2 | 3957·4 | 3961·6 | 3965·8 | 3970·0 | 3974·2 | 3978·4 | 3982·6 | 3986·7 | 4·2 |
| 169 | 4 3990·9 | 3995·1 | 3999·3 | 4003·5 | 4007·7 | 4011·9 | 4016·0 | 4020·2 | 4024·4 | 4028·6 | 4·2 |
| 170 | 4032·7 | 4036·9 | 4041·1 | 4045·2 | 4049·4 | 4053·6 | 4057·7 | 4061·9 | 4066·0 | 4070·2 | 4·2 |
| 171 | 4074·3 | 4078·5 | 4082·6 | 4086·8 | 4090·9 | 4095·1 | 4099·2 | 4103·3 | 4107·5 | 4111·6 | 4·1 |
| 172 | 4 4115·7 | 4119·9 | 4124·0 | 4128·1 | 4132·3 | 4136·4 | 4140·5 | 4144·6 | 4148·7 | 4152·9 | 4·1 |
| 173 | 4157·0 | 4161·1 | 4165·2 | 4169·3 | 4173·4 | 4177·5 | 4181·6 | 4185·7 | 4189·8 | 4193·9 | 4·1 |
| 174 | 4198·0 | 4202·1 | 4206·2 | 4210·3 | 4214·4 | 4218·5 | 4222·6 | 4226·7 | 4230·8 | 4234·8 | 4·1 |
| 175 | 4 4238·9 | 4243·0 | 4247·1 | 4251·2 | 4255·3 | 4259·3 | 4263·4 | 4267·5 | 4271·5 | 4275·6 | 4·1 |
| 176 | 4279·6 | 4283·7 | 4287·8 | 4291·8 | 4295·9 | 4300·0 | 4304·0 | 4308·0 | 4312·1 | 4316·1 | 4·1 |
| 177 | 4320·2 | 4324·2 | 4328·3 | 4332·3 | 4336·4 | 4340·4 | 4344·4 | 4348·5 | 4352·5 | 4356·5 | 4·0 |
| 178 | 4 4360·5 | 4364·6 | 4368·6 | 4372·6 | 4376·6 | 4380·7 | 4384·7 | 4388·7 | 4392·7 | 4396·7 | 4·0 |
| 179 | 4400·7 | 4404·7 | 4408·8 | 4412·8 | 4416·8 | 4420·8 | 4424·8 | 4428·8 | 4432·8 | 4436·8 | 4·0 |
| 180 | 4440·8 | 4444·7 | 4448·7 | 4452·7 | 4456·7 | 4460·7 | 4464·7 | 4468·7 | 4472·6 | 4476·6 | 4·0 |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 181 | 23 3·1134 | 3·1156 | 3·1178 | 3·1200 | 3·1222 | 3·1244 | 3·1266 | 3·1287 | 3·1309 | 3·1331 | ·0022 |
| 182 | 3·1353 | 3·1375 | 3·1396 | 3·1418 | 3·1440 | 3·1461 | 3·1483 | 3·1505 | 3·1526 | 3·1548 | ·0022 |
| 183 | 3·1569 | 3·1591 | 3·1613 | 3·1634 | 3·1656 | 3·1677 | 3·1698 | 3·1720 | 3·1741 | 3·1763 | ·0021 |
| 184 | 23 3·1784 | 3·1805 | 3·1827 | 3·1848 | 3·1869 | 3·1891 | 3·1912 | 3·1933 | 3·1954 | 3·1975 | ·0021 |
| 185 | 3·1997 | 3·2018 | 3·2039 | 3·2060 | 3·2081 | 3·2102 | 3·2123 | 3·2144 | 3·2165 | 3·2186 | ·0021 |
| 186 | 3·2207 | 3·2228 | 3·2249 | 3·2270 | 3·2291 | 3·2312 | 3·2333 | 3·2353 | 3·2374 | 3·2395 | ·0021 |
| 187 | 23 3·2416 | 3·2437 | 3·2457 | 3·2478 | 3·2499 | 3·2520 | 3·2540 | 3·2561 | 3·2582 | 3·2602 | ·0021 |
| 188 | 3·2623 | 3·2643 | 3·2664 | 3·2685 | 3·2705 | 3·2726 | 3·2746 | 3·2767 | 3·2787 | 3·2808 | ·0021 |
| 189 | 3·2828 | 3·2848 | 3·2869 | 3·2889 | 3·2909 | 3·2930 | 3·2950 | 3·2970 | 3·2991 | 3·3011 | ·0020 |
| 190 | 23 3·3031 | 3·3051 | 3·3072 | 3·3092 | 3·3112 | 3·3132 | 3·3152 | 3·3172 | 3·3192 | 3·3212 | ·0020 |
| 191 | 3·3233 | 3·3253 | 3·3273 | 3·3293 | 3·3313 | 3·3333 | 3·3353 | 3·3372 | 3·3392 | 3·3412 | ·0020 |
| 192 | 3·3432 | 3·3452 | 3·3472 | 3·3492 | 3·3511 | 3·3531 | 3·3551 | 3·3571 | 3·3590 | 3·3610 | ·0020 |
| 193 | 23 3·3630 | 3·3649 | 3·3669 | 3·3689 | 3·3708 | 3·3728 | 3·3747 | 3·3767 | 3·3786 | 3·3806 | ·0020 |
| 194 | 3·3825 | 3·3845 | 3·3864 | 3·3884 | 3·3903 | 3·3922 | 3·3942 | 3·3961 | 3·3980 | 3·4000 | ·0019 |
| 195 | 3·4019 | 3·4038 | 3·4057 | 3·4077 | 3·4096 | 3·4115 | 3·4134 | 3·4153 | 3·4172 | 3·4192 | ·0019 |
| 196 | 23 3·4211 | 3·4230 | 3·4249 | 3·4268 | 3·4287 | 3·4306 | 3·4325 | 3·4344 | 3·4362 | 3·4381 | ·0019 |
| 197 | 3·4400 | 3·4419 | 3·4438 | 3·4457 | 3·4476 | 3·4494 | 3·4513 | 3·4532 | 3·4550 | 3·4569 | ·0019 |
| 198 | 3·4588 | 3·4606 | 3·4625 | 3·4644 | 3·4662 | 3·4681 | 3·4699 | 3·4718 | 3·4736 | 3·4755 | ·0019 |
| 199 | 23 3·4773 | 3·4791 | 3·4810 | 3·4828 | 3·4846 | 3·4865 | 3·4883 | 3·4901 | 3·4920 | 3·4938 | ·0018 |
| 200 | 3·4956 | 3·4974 | 3·4992 | 3·5010 | 3·5028 | 3·5047 | 3·5065 | 3·5083 | 3·5101 | 3·5119 | ·0018 |
| 201 | 3·5137 | 3·5155 | 3·5172 | 3·5190 | 3·5208 | 3·5226 | 3·5244 | 3·5262 | 3·5280 | 3·5297 | ·0018 |
| 202 | 23 3·5315 | 3·5333 | 3·5351 | 3·5368 | 3·5386 | 3·5404 | 3·5421 | 3·5439 | 3·5456 | 3·5474 | ·0018 |
| 203 | 3·5492 | 3·5509 | 3·5527 | 3·5544 | 3·5561 | 3·5579 | 3·5596 | 3·5614 | 3·5631 | 3·5648 | ·0017 |
| 204 | 3·5666 | 3·5683 | 3·5700 | 3·5717 | 3·5735 | 3·5752 | 3·5769 | 3·5786 | 3·5803 | 3·5820 | ·0017 |
| 205 | 23 3·5837 | 3·5854 | 3·5871 | 3·5888 | 3·5905 | 3·5922 | 3·5939 | 3·5956 | 3·5973 | 3·5990 | ·0017 |
| 206 | 3·6007 | 3·6024 | 3·6040 | 3·6057 | 3·6074 | 3·6091 | 3·6107 | 3·6124 | 3·6141 | 3·6157 | ·0017 |
| 207 | 3·6174 | 3·6191 | 3·6207 | 3·6224 | 3·6240 | 3·6257 | 3·6273 | 3·6290 | 3·6306 | 3·6323 | ·0016 |
| 208 | 23 3·6339 | 3·6355 | 3·6372 | 3·6388 | 3·6404 | 3·6420 | 3·6437 | 3·6453 | 3·6469 | 3·6485 | ·0016 |
| 209 | 3·6502 | 3·6518 | 3·6534 | 3·6550 | 3·6566 | 3·6582 | 3·6598 | 3·6614 | 3·6630 | 3·6646 | ·0016 |
| 210 | 3·6662 | 3·6678 | 3·6694 | 3·6710 | 3·6726 | 3·6741 | 3·6757 | 3·6773 | 3·6789 | 3·6805 | ·0016 |
| 211 | 23 3·6820 | 3·6836 | 3·6852 | 3·6867 | 3·6883 | 3·6899 | 3·6914 | 3·6930 | 3·6946 | 3·6961 | ·0016 |
| 212 | 3·6977 | 3·6992 | 3·7008 | 3·7023 | 3·7039 | 3·7054 | 3·7070 | 3·7085 | 3·7100 | 3·7116 | ·0015 |
| 213 | 3·7131 | 3·7146 | 3·7162 | 3·7177 | 3·7192 | 3·7207 | 3·7223 | 3·7238 | 3·7253 | 3·7268 | ·0015 |
| 214 | 23 3·7283 | 3·7298 | 3·7313 | 3·7329 | 3·7344 | 3·7359 | 3·7374 | 3·7389 | 3·7404 | 3·7419 | ·0015 |
| 215 | 3·7434 | 3·7448 | 3·7463 | 3·7478 | 3·7493 | 3·7508 | 3·7523 | 3·7538 | 3·7552 | 3·7567 | ·0015 |
| 216 | 3·7582 | 3·7597 | 3·7612 | 3·7626 | 3·7641 | 3·7656 | 3·7670 | 3·7685 | 3·7700 | 3·7714 | ·0015 |
| 217 | 23 3·7729 | 3·7743 | 3·7758 | 3·7772 | 3·7787 | 3·7801 | 3·7816 | 3·7830 | 3·7845 | 3·7859 | ·0014 |
| 218 | 3·7874 | 3·7888 | 3·7902 | 3·7917 | 3·7931 | 3·7945 | 3·7960 | 3·7974 | 3·7988 | 3·8002 | ·0014 |
| 219 | 3·8016 | 3·8031 | 3·8045 | 3·8059 | 3·8073 | 3·8087 | 3·8101 | 3·8115 | 3·8129 | 3·8144 | ·0014 |
| 220 | 23 3·8158 | 3·8172 | 3·8186 | 3·8200 | 3·8214 | 3·8227 | 3·8241 | 3·8255 | 3·8269 | 3·8283 | ·0014 |
| 221 | 3·8297 | 3·8311 | 3·8325 | 3·8338 | 3·8352 | 3·8366 | 3·8380 | 3·8394 | 3·8407 | 3·8421 | ·0014 |
| 222 | 3·8435 | 3·8448 | 3·8462 | 3·8476 | 3·8489 | 3·8503 | 3·8517 | 3·8530 | 3·8544 | 3·8557 | ·0014 |
| 223 | 23 3·8571 | 3·8584 | 3·8598 | 3·8611 | 3·8625 | 3·8638 | 3·8651 | 3·8665 | 3·8678 | 3·8692 | ·0013 |
| 224 | 3·8705 | 3·8718 | 3·8732 | 3·8745 | 3·8758 | 3·8772 | 3·8785 | 3·8798 | 3·8811 | 3·8824 | ·0013 |
| 225 | 3·8838 | 3·8851 | 3·8864 | 3·8877 | 3·8890 | 3·8903 | 3·8916 | 3·8930 | 3·8943 | 3·8956 | ·0013 |
| 226 | 23 3·8969 | 3·8982 | 3·8995 | 3·9008 | 3·9021 | 3·9034 | 3·9047 | 3·9059 | 3·9072 | 3·9085 | ·0013 |
| 227 | 3·9098 | 3·9111 | 3·9124 | 3·9137 | 3·9150 | 3·9162 | 3·9175 | 3·9188 | 3·9201 | 3·9214 | ·0013 |
| 228 | 3·9226 | 3·9239 | 3·9252 | 3·9264 | 3·9277 | 3·9290 | 3·9303 | 3·9315 | 3·9328 | 3·9341 | ·0013 |
| 229 | 23 3·9353 | 3·9366 | 3·9378 | 3·9391 | 3·9404 | 3·9416 | 3·9429 | 3·9441 | 3·9454 | 3·9467 | ·0013 |
| 230 | 3·9479 | 3·9492 | 3·9504 | 3·9517 | 3·9529 | 3·9542 | 3·9554 | 3·9567 | 3·9579 | 3·9592 | ·0013 |
| 231 | 3·9604 | 3·9617 | 3·9629 | 3·9642 | 3·9654 | 3·9667 | 3·9679 | 3·9692 | 3·9704 | 3·9716 | ·0012 |
| 232 | 23 3·9729 | 3·9741 | 3·9754 | 3·9766 | 3·9779 | 3·9791 | 3·9803 | 3·9816 | 3·9828 | 3·9841 | ·0012 |
| 233 | 3·9853 | 3·9866 | 3·9878 | 3·9890 | 3·9903 | 3·9915 | 3·9927 | 3·9940 | 3·9952 | 3·9965 | ·0012 |
| 234 | 3·9977 | 3·9989 | 4·0002 | 4·0014 | 4·0026 | 4·0039 | 4·0051 | 4·0063 | 4·0076 | 4·0088 | ·0012 |
| 235 | 23 4·0100 | 4·0113 | 4·0125 | 4·0137 | 4·0150 | 4·0162 | 4·0174 | 4·0186 | 4·0199 | 4·0211 | ·0012 |
| 236 | 4·0223 | 4·0236 | 4·0248 | 4·0260 | 4·0272 | 4·0284 | 4·0297 | 4·0309 | 4·0321 | 4·0334 | ·0012 |
| 237 | 4·0346 | 4·0358 | 4·0370 | 4·0383 | 4·0395 | 4·0407 | 4·0419 | 4·0431 | 4·0444 | 4·0456 | ·0012 |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 181 | 4 4480·6 | 4484·6 | 4488·5 | 4492·5 | 4496·5 | 4500·5 | 4504·4 | 4508·4 | 4512·4 | 4516·3 | 4·0 |
| 182 | 4520·3 | 4524·2 | 4528·2 | 4532·2 | 4536·1 | 4540·1 | 4544·0 | 4548·0 | 4551·9 | 4555·9 | 4·0 |
| 183 | 4559·8 | 4563·7 | 4567·7 | 4571·6 | 4575·6 | 4579·5 | 4583·4 | 4587·4 | 4591·3 | 4595·2 | 3·9 |
| 184 | 4 4599·2 | 4603·1 | 4607·0 | 4610·9 | 4614·9 | 4618·8 | 4622·7 | 4626·6 | 4630·5 | 4634·4 | 3·9 |
| 185 | 4638·4 | 4642·3 | 4646·2 | 4650·1 | 4654·0 | 4657·9 | 4661·8 | 4665·7 | 4669·6 | 4673·5 | 3·9 |
| 186 | 4677·4 | 4681·3 | 4685·2 | 4689·1 | 4693·0 | 4696·9 | 4700·8 | 4704·6 | 4708·5 | 4712·4 | 3·9 |
| 187 | 4 4716·3 | 4720·2 | 4724·1 | 4727·9 | 4731·8 | 4735·7 | 4739·6 | 4743·4 | 4747·3 | 4751·2 | 3·9 |
| 188 | 4755·0 | 4758·9 | 4762·8 | 4766·7 | 4770·5 | 4774·4 | 4778·2 | 4782·1 | 4786·0 | 4789·8 | 3·9 |
| 189 | 4793·7 | 4797·5 | 4801·4 | 4805·2 | 4809·1 | 4812·9 | 4816·8 | 4820·6 | 4824·5 | 4828·3 | 3·8 |
| 190 | 4 4832·2 | 4836·0 | 4839·8 | 4843·7 | 4847·5 | 4851·4 | 4855·2 | 4859·0 | 4862·8 | 4866·7 | 3·8 |
| 191 | 4870·5 | 4874·3 | 4878·1 | 4882·0 | 4885·8 | 4889·6 | 4893·4 | 4897·3 | 4901·1 | 4904·9 | 3·8 |
| 192 | 4908·7 | 4912·5 | 4916·3 | 4920·1 | 4923·9 | 4927·7 | 4931·5 | 4935·3 | 4939·1 | 4942·9 | 3·8 |
| 193 | 4 4946·7 | 4950·5 | 4954·3 | 4958·1 | 4961·9 | 4965·7 | 4969·4 | 4973·2 | 4977·0 | 4980·7 | 3·8 |
| 194 | 4984·5 | 4988·3 | 4992·1 | 4995·8 | 4999·6 | 5003·4 | 5007·1 | 5010·9 | 5014·7 | 5018·4 | 3·8 |
| 195 | 5022·2 | 5025·9 | 5029·7 | 5033·4 | 5037·2 | 5040·9 | 5044·7 | 5048·4 | 5052·1 | 5055·9 | 3·7 |
| 196 | 4 5059·6 | 5063·4 | 5067·1 | 5070·8 | 5074·6 | 5078·3 | 5082·0 | 5085·7 | 5089·4 | 5093·1 | 3·7 |
| 197 | 5096·9 | 5100·6 | 5104·3 | 5108·0 | 5111·7 | 5115·4 | 5119·1 | 5122·8 | 5126·5 | 5130·2 | 3·7 |
| 198 | 5133·9 | 5137·5 | 5141·2 | 5144·9 | 5148·6 | 5152·3 | 5156·0 | 5159·6 | 5163·3 | 5166·9 | 3·7 |
| 199 | 4 5170·6 | 5174·3 | 5177·9 | 5181·6 | 5185·2 | 5188·9 | 5192·5 | 5196·2 | 5199·8 | 5203·4 | 3·6 |
| 200 | 5207·1 | 5210·7 | 5214·3 | 5218·0 | 5221·6 | 5225·2 | 5228·8 | 5232·5 | 5236·1 | 5239·7 | 3·6 |
| 201 | 5243·3 | 5246·9 | 5250·5 | 5254·1 | 5257·7 | 5261·3 | 5264·9 | 5268·5 | 5272·1 | 5275·7 | 3·6 |
| 202 | 4 5279·2 | 5282·8 | 5286·4 | 5290·0 | 5293·6 | 5297·2 | 6300·7 | 5304·3 | 5307·8 | 5311·4 | 3·6 |
| 203 | 5314·9 | 5318·5 | 5322·0 | 5325·6 | 5329·1 | 5332·7 | 5336·2 | 5339·7 | 5343·3 | 5346·8 | 3·5 |
| 204 | 5350·3 | 5353·8 | 5357·3 | 5360·9 | 5364·4 | 5367·9 | 5371·4 | 5374·9 | 5378·4 | 5381·9 | 3·5 |
| 205 | 4 5385·4 | 5388·9 | 5392·4 | 5395·9 | 5399·4 | 5402·9 | 5406·3 | 5409·8 | 5413·3 | 5416·7 | 3·5 |
| 206 | 5420·2 | 5423·7 | 5427·1 | 5430·6 | 5434·1 | 5437·5 | 5441·0 | 5444·4 | 5447·8 | 5451·3 | 3·5 |
| 207 | 5454·7 | 5458·1 | 5461·6 | 5465·0 | 5468·4 | 5471·9 | 5475·3 | 5478·7 | 5482·1 | 5485·5 | 3·4 |
| 208 | 4 5488·9 | 5492·3 | 5495·7 | 5499·1 | 5502·5 | 5505·9 | 5509·3 | 5512·7 | 5516·1 | 5519·4 | 3·4 |
| 209 | 5522·8 | 5526·2 | 5529·6 | 5532·9 | 5536·3 | 5539·7 | 5543·0 | 5546·4 | 5549·7 | 5553·1 | 3·4 |
| 210 | 5556·4 | 5559·8 | 5563·1 | 5566·4 | 5569·8 | 5573·1 | 5576·5 | 5579·8 | 5583·1 | 5586·4 | 3·3 |
| 211 | 4 5589·7 | 5593·0 | 5596·4 | 5599·7 | 5603·0 | 5606·3 | 5609·6 | 5612·9 | 5616·2 | 5619·5 | 3·3 |
| 212 | 5922·8 | 5626·1 | 5629·3 | 5632·6 | 5635·9 | 5639·2 | 5642·5 | 5645·7 | 5649·0 | 5652·3 | 3·3 |
| 213 | 5655·5 | 5658·8 | 5662·0 | 5665·3 | 5668·6 | 5671·8 | 5675·1 | 5678·3 | 5681·5 | 5684·8 | 3·2 |
| 214 | 4 5688·0 | 5691·2 | 5694·5 | 5697·7 | 5700·9 | 5704·2 | 5707·4 | 5710·6 | 5713·8 | 5717·0 | 3·2 |
| 215 | 5720·2 | 5723·4 | 5726·6 | 5729·9 | 5733·1 | 5736·3 | 5739·5 | 5742·6 | 5745·8 | 5749·0 | 3·2 |
| 216 | 5752·2 | 5755·4 | 5758·6 | 5761·8 | 5764·9 | 5768·1 | 5771·3 | 5774·4 | 5777·6 | 5780·8 | 3·2 |
| 217 | 4 5783·9 | 5787·1 | 5790·2 | 5793·4 | 5796·6 | 5799·7 | 5802·9 | 5806·0 | 5809·1 | 5812·2 | 3·1 |
| 218 | 5815·4 | 5818·5 | 5821·6 | 5824·8 | 5827·9 | 5831·0 | 5834·1 | 5837·3 | 5840·4 | 5843·5 | 3·1 |
| 219 | 5846·6 | 5849·7 | 5852·8 | 5855·9 | 5859·0 | 5862·1 | 5865·2 | 5868·3 | 5871·4 | 5874·4 | 3·1 |
| 220 | 4 5877·5 | 5880·6 | 5883·7 | 5886·8 | 5889·9 | 5893·0 | 5896·0 | 5899·1 | 5902·1 | 5905·2 | 3·1 |
| 221 | 5808·3 | 5911·3 | 5914·4 | 5917·4 | 5920·5 | 5923·6 | 5926·6 | 5929·6 | 5932·7 | 5935·7 | 3·0 |
| 222 | 5938·7 | 5941·8 | 5944·8 | 5947·8 | 5950·9 | 5953·9 | 5956·9 | 5959·9 | 5963·0 | 5966·0 | 3·0 |
| 223 | 4 5969·0 | 5972·0 | 5975·0 | 5978·0 | 5981·0 | 5984·0 | 5987·0 | 5990·0 | 5993·0 | 5996·0 | 3·0 |
| 224 | 5999·0 | 6002·0 | 6004·9 | 6007·9 | 6010·9 | 6013·9 | 6016·9 | 6019·8 | 6022·8 | 6025·8 | 3·0 |
| 225 | 6028·7 | 6031·7 | 6034·6 | 6037·6 | 6040·5 | 6043·5 | 6046·5 | 6049·4 | 6052·4 | 6055·3 | 3·0 |
| 226 | 4 6058·3 | 6061·2 | 6064·1 | 6067·1 | 6070·0 | 6072·9 | 6075·9 | 6078·8 | 6081·7 | 6084·7 | 2·9 |
| 227 | 6087·6 | 6090·5 | 6093·4 | 6096·3 | 6099·3 | 6102·2 | 6105·1 | 6108·0 | 6110·9 | 6113·8 | 2·9 |
| 228 | 6116·7 | 6119·6 | 6122·5 | 6125·4 | 6128·3 | 6131·2 | 6134·1 | 6137·0 | 6139·9 | 6142·8 | 2·9 |
| 229 | 4 6145·7 | 6148·6 | 6151·5 | 6154·4 | 6157·3 | 6160·2 | 6163·1 | 6166·0 | 6168·8 | 6171·7 | 2·9 |
| 230 | 6174·6 | 6177·5 | 6180·4 | 6183·3 | 6186·2 | 6189·1 | 6191·9 | 6194·8 | 6197·7 | 6200·6 | 2·9 |
| 231 | 6203·5 | 6206·4 | 6209·3 | 6212·1 | 6215·0 | 6217·9 | 6220·8 | 6223·7 | 6226·6 | 6229·5 | 2·9 |
| 232 | 4 6232·3 | 6235·2 | 6238·1 | 6241·0 | 6243·9 | 6246·8 | 6249·7 | 6252·6 | 6255·4 | 6258·3 | 2·9 |
| 233 | 6261·2 | 6264·1 | 6267·0 | 6269·9 | 6272·8 | 6275·7 | 6278·6 | 6281·5 | 6284·3 | 6287·2 | 2·9 |
| 234 | 6290·1 | 6293·0 | 6295·9 | 6298·8 | 6301·7 | 6304·6 | 6307·5 | 6310·4 | 6313·3 | 6316·2 | 2·9 |
| 235 | 4 6319·0 | 6322·0 | 6324·9 | 6327·7 | 6330·6 | 6333·5 | 6336·4 | 6339·3 | 6342·2 | 6345·1 | 2·9 |
| 236 | 6348·0 | 6350·9 | 6353·8 | 6356·7 | 6359·6 | 6362·5 | 6365·4 | 6368·3 | 6371·2 | 6374·1 | 2·9 |
| 237 | 6377·0 | 6379·9 | 6382·8 | 6385·7 | 6388·6 | 6391·5 | 6394·4 | 6397·3 | 6400·2 | 6403·1 | 2·9 |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | + |
| 238 | 23 4·0468 | 4·0480 | 4·0492 | 4·0505 | 4·0517 | 4·0529 | 4·0541 | 4·0553 | 4·0566 | 4·0578 | ·0012 |
| 239 | 4·0590 | 4·0602 | 4·0614 | 4·0626 | 4·0639 | 4·0651 | 4·0663 | 4·0675 | 4·0687 | 4·0699 | ·0012 |
| 240 | 4·0711 | 4·0724 | 4·0736 | 4.0748 | 4·0760 | 4·0772 | 4·0784 | 4·0796 | 4·0809 | 4·0821 | ·0012 |
| 241 | 23 4·0833 | 4·0845 | 4·0857 | 4·0869 | 4·0881 | 4·0893 | 4·0905 | 4·0917 | 4·0930 | 4·0942 | ·0012 |
| 242 | 4·0954 | 4·0966 | 4·0978 | 4·0990 | 4·1002 | 4·1014 | 4·1026 | 4·1038 | 4·1050 | 4·1062 | ·0012 |
| 243 | 4·1074 | 4·1087 | 4·1099 | 4·1111 | 4·1123 | 4·1135 | 4·1147 | 4·1159 | 4·1171 | 4·1183 | ·0012 |
| 244 | 23 4·1195 | 4·1207 | 4·1219 | 4·1231 | 4·1243 | 4·1255 | 4·1267 | 4·1279 | 4·1291 | 4·1303 | ·0012 |
| 245 | 4·1315 | 4·1327 | 4·1339 | 4·1351 | 4·1363 | 4·1375 | 4·1387 | 4·1399 | 4·1411 | 4·1423 | ·0012 |
| 246 | 4·1435 | 4·1447 | 4·1459 | 4·1471 | 4·1483 | 4·1495 | 4·1506 | 4·1518 | 4·1530 | 4·1542 | ·0012 |
| 247 | 23 4·1554 | 4·1566 | 4·1578 | 4·1590 | 4·1602 | 4·1614 | 4·1626 | 4·1638 | 4·1649 | 4·1661 | ·0012 |
| 248 | 4·1673 | 4·1685 | 4·1697 | 4·1709 | 4·1721 | 4·1733 | 4·1744 | 4·1756 | 4·1768 | 4·1780 | ·0012 |
| 249 | 4·1792 | 4·1804 | 4·1815 | 4·1827 | 4·1839 | 4·1851 | 4·1863 | 4·1874 | 4·1886 | 4·1898 | ·0012 |
| 250 | 23 4·1910 | 4·1922 | 4·1933 | 4·1945 | 4·1957 | 4·1969 | 4·1980 | 4·1992 | 4·2004 | 4·2015 | ·0012 |
| 251 | 4·2027 | 4·2039 | 4·2051 | 4·2062 | 4·2074 | 4·2086 | 4·2097 | 4·2109 | 4·2121 | 4·2132 | ·0012 |
| 252 | 4·2144 | 4·2156 | 4·2167 | 4·2179 | 4·2190 | 4·2202 | 4·2214 | 4·2225 | 4·2237 | 4·2248 | ·0012 |
| 253 | 23 4·2260 | 4·2272 | 4·2283 | 4·2295 | 4·2306 | 4·2318 | 4·2329 | 4·2341 | 4·2352 | 4·2364 | ·0012 |
| 254 | 4·2375 | 4·2387 | 4·2398 | 4·2410 | 4·2421 | 4·2433 | 4·2444 | 4·2455 | 4·2467 | 4·2178 | ·0011 |
| 255 | 4·2490 | 4·2501 | 4·2513 | 4·2524 | 4·2535 | 4·2547 | 4·2558 | 4·2569 | 4·2581 | 4·2592 | ·0011 |
| 256 | 23 4·2603 | 4·2615 | 4·2626 | 4·2637 | 4·2648 | 4·2660 | 4·2671 | 4·2682 | 4·2693 | 4·2705 | ·0011 |
| 257 | 4·2716 | 4·2727 | 4·2738 | 4·2749 | 4·2760 | 4·2772 | 4·2783 | 4·2794 | 4·2805 | 4·2816 | ·0011 |
| 258 | 4·2827 | 4·2838 | 4·2849 | 4·2860 | 4·2871 | 4·2882 | 4·2893 | 4·2904 | 4·2915 | 4·2926 | ·0011 |
| 259 | 23 4·2937 | 4·2948 | 4·2959 | 4·2970 | 4·2981 | 4·2992 | 4·3003 | 4·3014 | 4·3025 | 4·3036 | ·0011 |
| 260 | 4·3046 | 4·3057 | 4·3068 | 4·3079 | 4·3090 | 4·3101 | 4·3111 | 4·3122 | 4·3133 | 4·3144 | ·0011 |
| 261 | 4·3154 | 4·3165 | 4·3176 | 4·3187 | 4·3197 | 4·3208 | 4·3219 | 4·3229 | 4·3240 | 4·3250 | ·0011 |
| 262 | 23 4·3261 | 4·3272 | 4·3282 | 4·3293 | 4·3303 | 4·3314 | 4·3325 | 4·3335 | 4·3346 | 4·3356 | ·0011 |
| 263 | 4·3367 | 4·3377 | 4·3388 | 4·3398 | 4·3409 | 4·3419 | 4·3429 | 4·3440 | 4·3450 | 4·3461 | ·0010 |
| 264 | 4·3471 | 4·3482 | 4·3492 | 4·3502 | 4·3513 | 4·3523 | 4·3533 | 4·3544 | 4·3554 | 4·3564 | ·0010 |
| 265 | 23 4·3574 | 4·3585 | 4·3595 | 4·3605 | 4·3615 | 4·3626 | 4·3636 | 4·3646 | 4·3656 | 4·3667 | ·0010 |
| 266 | 4·3677 | 4·3687 | 4·3697 | 4·3707 | 4·3717 | 4·3728 | 4·3738 | 4·3748 | 4·3758 | 4·3768 | ·0010 |
| 267 | 4·3778 | 4·3788 | 4·3798 | 4·3808 | 4·3818 | 4·3828 | 4·3838 | 4·3848 | 4·3858 | 4·3868 | ·0010 |
| 268 | 23 4·3878 | 4·3888 | 4·3898 | 4·3908 | 4·3918 | 4·3928 | 4·3938 | 4·3948 | 4·3958 | 4·3968 | ·0010 |
| 269 | 4·3977 | 4·3987 | 4·3997 | 4·4007 | 4·4017 | 4·4027 | 4·4036 | 4·4046 | 4·4056 | 4·4066 | ·0010 |
| 270 | 4·4075 | 4·4085 | 4·4095 | 4·4105 | 4·4114 | 4·4124 | 4·4134 | 4·4143 | 4·4153 | 4·4163 | ·0010 |
| 271 | 23 4·4172 | 4·4182 | 4·4192 | 4·4201 | 4·4211 | 4·4220 | 4·4230 | 4·4240 | 4·4249 | 4·4259 | ·0010 |
| 272 | 4·4268 | 4·4278 | 4·4287 | 4·4297 | 4·4307 | 4·4316 | 4·4326 | 4·4335 | 4·4344 | 4·4354 | ·0010 |
| 273 | 4·4363 | 4·4373 | 4·4382 | 4·4392 | 4·4401 | 4·4411 | 4·4420 | 4·4429 | 4·4439 | 4·4448 | ·0009 |
| 274 | 23 4·4457 | 4·4467 | 4·4476 | 4·4485 | 4·4495 | 4·4504 | 4·4513 | 4·4523 | 4·4532 | 4·4541 | ·0009 |
| 275 | 4·4551 | 4·4560 | 4·4569 | 4·4578 | 4·4587 | 4·4597 | 4·4606 | 4·4615 | 4·4624 | 4·4633 | ·0009 |
| 276 | 4·4643 | 4·4652 | 4·4661 | 4·4670 | 4·4679 | 4·4688 | 4·4697 | 4·4706 | 4·4715 | 4·4725 | ·0009 |
| 277 | 23 4·4734 | 4·4743 | 4·4752 | 4·4761 | 4·4770 | 4·4779 | 4·4788 | 4·4797 | 4·4806 | 4·4815 | ·0009 |
| 278 | 4·4824 | 4·4833 | 4·4842 | 4·4850 | 4·4859 | 4·4868 | 4·4877 | 4·4886 | 4·4895 | 4·4904 | ·0009 |
| 279 | 4·4913 | 4·4922 | 4·4930 | 4·4939 | 4·4948 | 4·4957 | 4·4966 | 4·4975 | 4·4983 | 4·4992 | ·0009 |
| 280 | 23 4·5001 | 4·5010 | 4·5018 | 4·5027 | 4·5036 | 4·5045 | 4·5053 | 4·5062 | 4·5071 | 4·5080 | ·0009 |
| 281 | 4·5088 | 4·5097 | 4·5105 | 4·5114 | 4·5123 | 4·5131 | 4·5140 | 4·5148 | 4·5157 | 4·5166 | ·0009 |
| 282 | 4·5174 | 4·5183 | 4·5191 | 4·5200 | 4·5208 | 4·5217 | 4·5226 | 4·5234 | 4·5243 | 4·5251 | ·0009 |
| 283 | 23 4·5260 | 4·5268 | 4·5277 | 4·5285 | 4·5293 | 4·5302 | 4·5310 | 4·5319 | 4·5327 | 4·5336 | ·0008 |
| 284 | 4·5344 | 4·5352 | 4·5361 | 4·5369 | 4·5378 | 4·5386 | 4·5394 | 4·5403 | 4·5411 | 4·5419 | ·0008 |
| 285 | 4·5427 | 4·5436 | 4·5444 | 4·5452 | 4·5461 | 4·5469 | 4·5477 | 4·5485 | 4·5494 | 4·5502 | ·0008 |
| 286 | 23 4·5510 | 4·5518 | 4·5527 | 4·5535 | 4·5543 | 4·5551 | 4·5559 | 4·5567 | 4·5576 | 4·5584 | ·0008 |
| 287 | 4·5592 | 4·5600 | 4·5608 | 4·5616 | 4·5624 | 4·5632 | 4·5641 | 4·5648 | 4·5657 | 4·5665 | ·0008 |
| 288 | 4·5673 | 4·5681 | 4·5689 | 4·5697 | 4·5705 | 4·5713 | 4·5721 | 4·5729 | 4·5737 | 4·5745 | ·0008 |
| 289 | 23 4·5753 | 4·5761 | 4·5769 | 4·5777 | 4·5785 | 4·5793 | 4·5800 | 4·5808 | 4·5816 | 4·5824 | ·0008 |
| 290 | 4·5832 |  |  |  |  |  |  |  |  |  |  |

| v | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| f.s. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | feet. | + |
| 238 | 4 6406·0 | 6408·9 | 6411·8 | 6414·8 | 6417·7 | 6420·6 | 6423·5 | 6426·4 | 6429·3 | 6432·2 | 2·9 |
| 239 | 6435·1 | 6438·0 | 6440·9 | 6443·8 | 6446·8 | 6449·7 | 6452·6 | 6455·5 | 6458·4 | 6461·3 | 2·9 |
| 240 | 6464·2 | 6467·1 | 6470·1 | 6473·0 | 6475·9 | 6478·8 | 6481·7 | 6484·6 | 6487·6 | 6490·5 | 2·9 |
| 241 | 4 6493·4 | 6496·3 | 6499·2 | 6502·2 | 6505·1 | 6508·0 | 6510·9 | 6513·8 | 6516·8 | 6519·7 | 2·9 |
| 242 | 6522·6 | 6525·6 | 6528·5 | 6531·4 | 6534·3 | 6537·3 | 6540·2 | 6543·1 | 6546·1 | 6549·0 | 2·9 |
| 243 | 6551·9 | 6554·9 | 6557·8 | 6560·7 | 6563·7 | 6566·6 | 6569·5 | 6572·5 | 6575·4 | 6578·3 | 2·9 |
| 244 | 4 6581·3 | 6584·2 | 6587·2 | 6590·1 | 6593·0 | 6596·0 | 6598·9 | 6601·8 | 6604·8 | 6607·7 | 2·9 |
| 245 | 6610·6 | 6613·6 | 6616·5 | 6619·5 | 6622·4 | 6625·3 | 6628·3 | 6631·2 | 6634·2 | 6637·1 | 2·9 |
| 246 | 6640·1 | 6643·0 | 6645·9 | 6648·9 | 6651·8 | 6654·8 | 6657·7 | 6660·6 | 6663·6 | 6666·5 | 2·9 |
| 247 | 4 6669·5 | 6672·4 | 6675·4 | 6678·3 | 6681·3 | 6684·2 | 6687·2 | 6690·1 | 6693·0 | 6696·0 | 2·9 |
| 248 | 6698·9 | 6701·9 | 6704·8 | 6707·8 | 6710·7 | 6713·7 | 6716·6 | 6719·6 | 6722·5 | 6725·5 | 2·9 |
| 249 | 6728·4 | 6731·3 | 6734·3 | 6737·2 | 6740·2 | 6743·1 | 6746·1 | 6749·0 | 6752·0 | 6754·9 | 2·9 |
| 250 | 4 6757·8 | 6760·7 | 6763·7 | 6766·7 | 6769·6 | 6772·6 | 6775·5 | 6778·4 | 6781·4 | 6784·3 | 2·9 |
| 251 | 6787·3 | 6790·2 | 6793·1 | 6796·1 | 6799·0 | 6802·0 | 6804·9 | 6807·8 | 6810·8 | 6813·7 | 2·9 |
| 252 | 6816·6 | 6819·6 | 6822·5 | 6825·4 | 6828·4 | 6831·3 | 6834·2 | 6837·1 | 6840·1 | 6843·0 | 2·9 |
| 253 | 4 6845·9 | 6848·8 | 6851·8 | 6854·7 | 6857·6 | 6860·5 | 6863·5 | 6866·4 | 6869·3 | 6872·2 | 2·9 |
| 254 | 6875·1 | 6878·1 | 6881·0 | 6883·9 | 6886·8 | 6889·7 | 6892·6 | 6895·6 | 6898·5 | 6901·4 | 2·9 |
| 255 | 6904·3 | 6907·2 | 6910·1 | 6913·0 | 6915·9 | 6918·8 | 6921·7 | 6924·6 | 6927·5 | 6930·4 | 2·9 |
| 256 | 4 6933·3 | 6936·2 | 6939·1 | 6942·0 | 6944·9 | 6947·8 | 6950·6 | 6953·5 | 6956·4 | 6959·3 | 2·9 |
| 257 | 6962·2 | 6965·0 | 6967·9 | 6970·8 | 6973·7 | 6976·5 | 6979·4 | 6982·3 | 6985·1 | 6988·0 | 2·9 |
| 258 | 6990·9 | 6993·7 | 6996·6 | 6999·4 | 7002·3 | 7005·1 | 7008·0 | 7010·8 | 7013·7 | 7016·5 | 2·9 |
| 259 | 4 7019·4 | 7022·2 | 7025·0 | 7027·9 | 7030·7 | 7033·5 | 7036·4 | 7039·2 | 7042·0 | 7044·8 | 2·8 |
| 260 | 7047·7 | 7050·5 | 7053·3 | 7056·1 | 7058·9 | 7061·7 | 7064·5 | 7067·4 | 7070·2 | 7073·0 | 2·8 |
| 261 | 7075·8 | 7078·6 | 7081·4 | 7084·2 | 7087·0 | 7089·7 | 7092·5 | 7095·3 | 7098·1 | 7100·9 | 2·8 |
| 262 | 4 7103·7 | 7106·5 | 7109·2 | 7112·0 | 7114·8 | 7117·6 | 7120·3 | 7123·1 | 7125·9 | 7128·6 | 2·8 |
| 263 | 7131·4 | 7134·2 | 7136·9 | 7139·7 | 7142·4 | 7145·2 | 7147·9 | 7150·7 | 7153·4 | 7156·2 | 2·8 |
| 264 | 7158·9 | 7161·7 | 7164·4 | 7167·1 | 7169·9 | 7172·6 | 7175·4 | 7178·1 | 7180·8 | 7183·5 | 2·7 |
| 265 | 4 7186·3 | 7189·0 | 7191·7 | 7294·4 | 7197·1 | 7199·9 | 7202·6 | 7205·3 | 7208·0 | 7210·7 | 2·7 |
| 266 | 7213·4 | 7216·1 | 7218·8 | 2221·5 | 7224·2 | 7226·9 | 7229·6 | 7232·3 | 7235·0 | 7237·7 | 2·7 |
| 267 | 7240·4 | 7243·1 | 7245·8 | 7248·5 | 7251·2 | 7253·8 | 7256·5 | 7259·2 | 7261·9 | 7264·5 | 2·7 |
| 268 | 4 7267·2 | 7269·9 | 7272·5 | 7275·2 | 7277·9 | 7280·5 | 7283·2 | 7285·9 | 7288·5 | 7291·2 | 2·7 |
| 269 | 7293·8 | 7296·5 | 7299·1 | 7301·8 | 7304·4 | 7307·1 | 7309·7 | 7312·3 | 7315 0 | 7317·6 | 2·6 |
| 270 | 7320·2 | 7322·9 | 7325·5 | 7328·1 | 7330·8 | 7333·4 | 7336·0 | 7338·6 | 7341·2 | 7343·9 | 2·6 |
| 271 | 4 7346·5 | 7349·1 | 7351·7 | 7354·3 | 7356·9 | 7359·5 | 7362·1 | 7364·7 | 7367·3 | 7369·9 | 2·6 |
| 272 | 7372·5 | 7375·1 | 7377·7 | 7380·3 | 7382·9 | 7385·5 | 7388·1 | 7390·7 | 7393·3 | 7395·8 | 2·6 |
| 273 | 7398·4 | 7401·0 | 7403·6 | 7406·2 | 7408·7 | 7411·3 | 7413·9 | 7416·4 | 7419·0 | 7421·6 | 2·6 |
| 274 | 4 7424·1 | 7426·7 | 7429·3 | 7431·8 | 7434·4 | 7436·9 | 7439·5 | 7442·0 | 7444·6 | 7447·1 | 2·6 |
| 275 | 7449·7 | 7452·2 | 7454·8 | 7457·3 | 7459·8 | 7462·4 | 7464·9 | 7467·4 | 7470·0 | 7472·5 | 2·5 |
| 276 | 7475·0 | 7477·5 | 7480·1 | 7482·6 | 7485·1 | 7487·6 | 7490·1 | 7492·7 | 7495·2 | 7497·7 | 2·5 |
| 277 | 4 7500·2 | 7502·7 | 7505·2 | 7507·7 | 7510·2 | 7512·7 | 7515·2 | 7517·7 | 7520·2 | 7522·7 | 2·5 |
| 278 | 7525·2 | 7527·7 | 7530·1 | 7532·6 | 7535·1 | 7537·6 | 7540·1 | 7542·6 | 7545·0 | 7547·5 | 2·5 |
| 279 | 7550·0 | 7552·4 | 7554·9 | 7557·4 | 7559·9 | 7562·3 | 7564·8 | 7567·2 | 7569·7 | 7572·2 | 2·5 |
| 280 | 4 7574·6 | 7577·1 | 7579·5 | 7582·0 | 7584·4 | 7586·8 | 7589·3 | 7591·7 | 7594·2 | 7596·6 | 2·4 |
| 281 | 7599·0 | 7601·5 | 7603·9 | 7606·4 | 7608·8 | 7611·2 | 7613·6 | 7616·1 | 7618·5 | 7620·9 | 2·4 |
| 282 | 7623·3 | 7625·7 | 7628·2 | 7630·6 | 7633·0 | 7635·4 | 7637·8 | 7640·2 | 7642·6 | 7645·0 | 2·4 |
| 283 | 4 7647·4 | 7649·8 | 7652·2 | 7654·6 | 7657·0 | 7659·4 | 7661·8 | 7664·2 | 7666·6 | 7669·0 | 2·4 |
| 284 | 7671·3 | 7673·7 | 7676·1 | 7678·5 | 7680·9 | 7683·3 | 7685·6 | 7688·0 | 7690·4 | 7692·7 | 2·4 |
| 285 | 7695·1 | 7697·5 | 7699·8 | 7702·2 | 7704·6 | 7706·9 | 7709·3 | 7711·6 | 7714·0 | 7716·4 | 2·4 |
| 286 | 4 7718·7 | 7721·1 | 7723·4 | 7725·8 | 7728·1 | 7730·4 | 7732·8 | 7735·1 | 7737·5 | 7739·8 | 2·3 |
| 287 | 7742·1 | 7744·5 | 7746·8 | 7749·1 | 7751·5 | 7753·8 | 7756·1 | 7758·4 | 7760·8 | 7763·1 | 2·3 |
| 288 | 7765·4 | 7767·7 | 7770·0 | 7772·4 | 7774·7 | 7777·0 | 7779·3 | 7781·6 | 7783·9 | 7786·2 | 2·3 |
| 289 | 4 7788·5 | 7790·8 | 7793·1 | 7795·4 | 7797·7 | 7800 0 | 7802·3 | 7804·6 | 7806·9 | 7809·2 | 2·3 |
| 290 | 7811·5 |  |  |  |  |  |  |  |  |  |  |

## TRAJECTORIES CALCULATED FROM CHRONOGRAPH VELOCITIES.

Before we can make any progress whatever, we must know the diameter and weight of the bullet. In all our Express rifles, we have the diameter ready to hand, the calibre being given in thousandths of an inch, as ·450, ·500, &c.; and the weight of the bullet is usually stated in grains. Having these particulars we proceed as follows:

We first square the diameter of the bullet, and then divide by its weight, so as to obtain a factor or co-efficient of air-resistance, which is the basis of every calculation with this bullet, and which, in writings on the subject, is commonly designated as its $\frac{d^2}{w}$. In the foregoing pages, the tables on the left-hand, headed by this symbol followed by the letter *t*, apply to calculations of *time*; those on the ~~left~~-hand pages, with an *s* after the symbol, apply to calculations of *space* or distance.

Let us suppose—to take an easy example—that the diameter is ·500 and that the bullet weighs 500 grains. We get the square of ·500 by multiplying it by itself; and, omitting the superfluous cyphers, the result is ·25. We have now to divide this by the weight; and, as the tables which have afterwards to be worked from are based on the weight of the projectile "in pounds," the number of grains in our bullet has to be reduced to the fraction of a pound. With 500 grains, we see at once that it is $\frac{1}{14}$th of a pound of 7000 grains; and, as the process of dividing by this fraction is the same as multiplying by 14, we should readily obtain the required result. Generally, however, the number of grains does not divide so easily, and the simplest method, in most cases, is to multiply by 7000 and divide by the number of grains in the bullet. This is, of course, merely the same as dividing by the fraction of a pound, which in our case is

$\frac{500}{7000}$, or $\frac{1}{14}$; and in many instances this method is more simple than that of ascertaining the corresponding decimal fraction, which for the 500 grain bullet would be ·07142857lb.

The division of the square of the diameter by the weight of our bullet will be seen to give 3·5 as the result; and if we want to know the remaining velocity of this bullet at any range—say, 100 yards—we must multiply the 3·5 by 300 (the number of feet in that range), which gives 1050 as the product. And now we are in a position to make use of the tables.

Supposing we know from the chronograph that the muzzle velocity of our bullet is 1685 feet per second, we refer to the table of "Space" (page 161), and in the line beginning 168, and the column headed 5, we find that 43970 is the number corresponding with 1685 velocity. We take this number, subtract therefrom the 1050 previously obtained for 100 yards, and the remainder is 42920. Referring again to the same table, we find that the nearest number to 42920 is in the line beginning with 144, and that, without resorting to fractions, the remaining velocity would be represented by 1448, or by 1447·6 if you wish to be more exact.

Having now obtained the "remaining velocity," you may desire to ascertain the time of flight or amount of drop of the bullet in the same distance; and for this purpose it is necessary to refer to the opposite page relative to "Time." You take from this, in similar fashion to the table previously used, the number corresponding to 1685 velocity, which is 232·8209; subtract therefrom the number corresponding to 1448, which would be 232·1494; and the remainder (·6715), divided by the 3·5 previously mentioned as the factor of air-resistance, gives you the fraction of a second (·191857) in which the bullet traversed the 100 yards range.

To ascertain the "drop," this fraction of a second has to be squared, which gives ·036809, and multiplied by 193 inches (or 193·145, if you wish to be very particular), as the gravity drop for 1 second, and this shows our bullet drop in 100 yards to be a trifle over 7·1 inches. There is a table in Mr. Bashforth's book from which the drop of the bullet can be read off by inspection, when you know the *time;* and it is very useful indeed for long ranges, where the drop is stated in feet; but for the short ranges required for sporting purposes, where the fractions of a second are very small, and the measurement must be given in inches, I prefer to calculate from the number 193·145, as if you take the fraction of a foot from the table and turn it into inches, any little divergency in the last figure of the decimal is multiplied 12 times in this process, and thus makes the differences between successive ranges appear out of proportion.

### CALCULATION OF DROP FROM MUZZLE VELOCITY.

The above long description may be briefly summarised in figures, with the aid of the ordinary arithmetical signs for multiplication, division, &c., the same dimensions, weight of bullet, velocity, &c., being given as before.

·500 × ·500 = ·25, square of diameter of bullet;
·25 × 7000 grs. = 1750;
1750 ÷ 500 grs. = 3·5, factor of air-resistance, or $\frac{d^2}{w}$

We now have recourse to Bashforth's tables as follows—selecting the "space number" from the right-hand page, and the "time number" from that on the left:

| | Space Number. | | Time Number. |
|---|---|---|---|
| 1685 ft.-sec. velocity | 43970 | 1685 ft.-sec. velocity | 232·8209 |
| – 3·5 × 300 feet ... | 1050 | | |
| | | Remaining velocity. | |
| | 42920 = | 1448 ft.-sec. = | 232·1494 |
| | | | ·6715 |

·6715 ÷ 3·5 = ·191857 sec. (Time of flight)
·191857 × ·191857 = ·036809 square of Time.
·036809 × 193 in. = 7·1 in. drop of bullet.

These calculations are, of course, much more rapidly made by logarithms than by ordinary arithmetic; and the process is so easily acquired, that it is well worth the while of anyone, not already acquainted with the process, to learn it before he indulges much in work of this kind.

It may also be as well to mention here that, if "drop" calculations for comparative purposes are about to be made, it may save time in the end to be very exact in estimating the "remaining velocity" to fractions of a foot. The time calculation is based on this remaining velocity; and any slight inaccuracy is considerably magnified by the squaring of the time, and will thus make a very noticeable difference in long ranges. The young beginner may therefore be greatly puzzled by irregularities of increase in drop at different ranges, and, fancying that his calculations are wrong, may work and re-work his figures to trace the error, whereas the inaccuracy may, after all, be only due to allowance not having been made for a fraction of a foot in the velocity.

### Calculation of Muzzle Velocity from Time or Drop.

If, now, you wish to ascertain the muzzle velocity from the mean velocity obtained by the chronograph, the above process, or a part of it, has to be reversed. Supposing that the mean velocity in 20 yards has been ascertained, that would, as recently stated, be the actual velocity at half-distance, or 10 yards. The factor of air-resistance, 3·5 (if the bullet were the one just mentioned), would have to be multiplied by the half-distance in feet (30), and the product *added* to the "Space" number taken from the right-hand table. This will give the number corresponding to the velocity at the muzzle, which is 30 feet from the point where the velocity is known.

If the amount of drop is known, and you wish to ascertain the muzzle velocity, it may be worked out by a further application of the reverse process just described. Taking the previous figures, by way of example, with 7·1in. drop of bullet, we proceed as follows :

7·1in. drop ÷ 193in. = ·036809 square of time;
Extract square root of ·036809 = ·191857 sec., Time of flight;
300 feet ÷ ·191857sec. = 1564 mean velocity in 100 yards;
Mean velocity in 100 yards = actual velocity at 50 yards.

Actual velocity, 1564 = 43448·6 in Space table;
add 150 feet × 3·5 = 525·0
and the remainder, 43973·6 = 1686 velocity in Space table.

The result here is only 1 foot different from the muzzle velocity previously mentioned, and that difference would have been less had fractions been resorted to, as the mean velocity was rather over 1563½ feet per second.

## CALCULATION OF TRAJECTORY WITHOUT A CHRONOGRAPH.

Few persons have a chronograph at their service, but many may like to carry out experiments within their means for the purpose of estimating the trajectories of their rifles or ascertaining the muzzle velocity. It is not to be expected that the results to be obtained by the methods now about to be described can be more than approximate, but the experiments, if carefully carried out, will often give a closer approximation than might be expected.

Col. Davidson, the inventor of the telescopic sight for rifles, in commenting, in the *Field,* on the recent rifle trial at Putney, thus described the method he adopts for ascertaining the trajectory and drop of bullets :

"Every gunmaker should be prepared to tell his customer what is the trajectory of the rifle he sells. Everyone has not the means of making such trials as you record. I have been in the habit of adopting a more simple method. Using my telescopic sight, and taking the line which represents no elevation at all (that is, the prolongation of the axis of barrel), I aim with that line at a spot the size of a shilling at the different distances from 25 to 200 yards; and, measuring from the centre of each group of shots, I note the fall of the bullet below the line of the axis of the piece. To lay down the trajectory, I have only to draw a line representing the prolongation of the axis, and mark off in that line the distances from 25 to 200 yards, and then lay off the drop of the bullet from each of these distances, when a curved line, connecting these points, will give the trajectory. Of course, for convenience, I use a different scale for the distances and for the drop."

From a line subtending the curve made as Col. Davidson describes, the height of the trajectory at different points could doubtless be ascertained with a very close approximation to accuracy; but I doubt whether measurement from the zero line, or line of no elevation, can be relied on to give a correct representation of the *actual* drop of the bullet in all cases; for the apparent drop and the actual drop are not necessarily the same. I am led to this remark by Col. Davidson having stated, in the course of his letter, that the drop of a rifle he tried he had found to be about 10 inches at 150 yards. A drop of 10 inches under the action of gravity is accomplished in less than a quarter of a second (·2275 sec.); and it will be seen, on dividing 450 feet by this time, that a bullet having so small a drop in 150 yards must have a *mean* velocity of over 1970 feet a second. To produce so high a mean velocity for that distance, the initial velocity of the bullet would have to be somewhere about 2600 feet per second. I conclude, therefore, that the apparent drop in Col. Davidson's bullet measured some inches less than the true drop—probably owing to a certain amount of "jump" in the rifle when fired. If, however, there be such a "jump" or other irregularity in the shooting as produces any material difference between the apparent and the real drop of the bullet, a clue to the fact may be found by taking the known height of the trajectory at mid-range, and multiplying it by 4, which will give approximately the drop at full range; so that, if any great difference is found to exist, it may be assumed that there is something wrong in the measurement of the apparent drop, although the curve of the trajectory itself may be right. It may be as well, moreover, instead of taking a single measurement from the centre of the group of shots, to go to the additional trouble of measuring every shot separately, and calculating the average; otherwise one might possibly have half a dozen bullets at different distances from the zero line, and only get the mean of the two extremes instead of the average of the entire group.

Another simple method of ascertaining trajectories is to fire a series of shots with the same sight at different distances in the following fashion. Let us suppose that half-a-dozen shots are fired from a sandbag or rest at 150 yards, and measurement made of the distance of each shot above or below a cross-line in the centre of the bullseye; the same is done with a similar half-dozen shots, 25 yards nearer, using the same sight, and aiming again at the centre of the bullseye; at 100, 75, 50, and 25 yards (or any other equal intervals that are convenient) the process is repeated, and measurements are taken. A straight line is drawn on a sheet of paper, and divided into equal distances to correspond with the divisions of the range, and at each division is plotted down the average measurement of the six shots above or below the line, as the case may be. When the whole are laid down, another straight line may be drawn from that part of the first line which corresponds with the position of the muzzle of the rifle, to the point which marks the average position of the six shots at 150 yards, and, if the rifle has been shot with equal accuracy at each distance, a curve drawn through the various points marked down in the range will represent the trajectory, and measurements from the base-line to the curve will give the height at any point. By measuring the height of the trajectory at a point a little beyond mid-distance (say 80 yards) and multiplying this height by 4, you get the total amount of drop in 150 yards; and from the drop you may, as recently pointed out, ascertain the time of flight, the mean velocity, and ultimately the muzzle velocity.

## The Vertex or Culminating Point of the Trajectory.

This occurs a little beyond mid-range, at about half the time of flight; and, taking 150 yards as a convenient range for Express rifles, 80 yards may, for all practical purposes, be assumed to representing the highest point of the trajectory; though with very light bullets and great speed the turning point would really be somewhat beyond 80 yards, and with heavy bullets and lower velocity it would be rather under that distance. Thus, a 360gr. bullet of ·450 bore, with 1600ft. muzzle velocity, would be at its highest about 79½ yards; whereas a 260gr. bullet, with 2000ft. initial velocity, would not reach its vertex till about 81 yards.

This, however, is on the supposition that the trajectory is calculated from a line produced from the axis of the barrel, without any allowance for the height of the front sight; but, if taken from the line of aim, the height of the front sight above the axis of the bore has to be allowed for, and this would vary in different rifles, according to the size of the bullet, the thickness of the barrel, and the height of the sight itself, and whether it were placed on the top of single-barrel, or on the rib of a double. Taking, however, half an inch as a convenient height of sight for our purpose, that would make a difference of a quarter of an inch at mid-range, and more or less as it was under or over 75 yards.

As the angle of elevation compensates for the bullet's drop throughout the whole range, it may be said to represent the average drop. During the first half of the time, when the speed is greatest, the bullet drops at a less rate than the angle rises; in the second half, the reverse is the case; and about midway, where there is an average of speed, the rise of angle and drop of bullet are brought into correspondence, and, for a few yards, the rise and fall so nearly counteract each other that recourse must be had to thousandths of an inch in order to mark the turning point. This will be seen by the following calculations of the respective heights of bullets of 260 and 360grs., with muzzle velocities of 2000ft. per second for the former and 1600 for the latter, so as to make a rather wide contrast:

HEIGHTS OF 150 YARDS TRAJECTORY BEYOND MID-RANGE, WITH NO ALLOWANCE FOR SIGHT.

| 260 GR. BULLET, WITH 2000 FT.-SEC. MUZZLE VELOCITY. | | 360 GR. BULLET WITH 1600 FT.-SEC. MUZZLE VELOCITY. | |
|---|---|---|---|
| At 75 yards | 4·059 inches. | At 75 yards | 5·590 inches. |
| 76 „ | 4·067 „ | 76 „ | 5·596 „ |
| 77 „ | 4·074 „ | 77 „ | 5·600 „ |
| 78 „ | 4·078 „ | 78 „ | 5·604 „ |
| 79 „ | 4·082 „ | 79 „ | 5·608 „ |
| 80 „ | 4·083 „ | 80 „ | 5·609 „ |
| 81 „ | 4·084 „ | 81 „ | 5·606 „ |
| 82 „ | 4·085 „ | 82 „ | 5·602 „ |
| 83 „ | 4·082 „ | 83 „ | 5·597 „ |

SAME, WITH HALF-INCH ALLOWANCE FOR SIGHT.

| | | | |
|---|---|---|---|
| At 79 yards | 3·844 inches. | At 77 yards | 5·357 inches. |
| 80 „ | 3·849 „ | 78 „ | 5·365 „ |
| 81 „ | 3·853 „ | 79 „ | 5·372 „ |
| 82 „ | 3·857 „ | 80 „ | 5·376 „ |
| 83 „ | 3·859 „ | 81 „ | 5·376 „ |
| 84 „ | 3·858 „ | 82 „ | 5·376 „ |
| 85 „ | 3·855 „ | 83 „ | 5·373 „ |

On comparing the first division of the table with the second it will be seen that, in the latter, the turning point appears to be removed a yard or two further on; and, with the slow bullet, the change is so gradual that even thousandths of an inch are not small enough to indicate the differences. This arises from the fact that, whereas the line of elevation increases in height with length of range, the allowance for sight diminishes; and thus another counteracting influence joins in with the diminishing velocity of the bullet, and gives almost absolute flatness for several yards. This is very convenient for amateurs who wish to calculate the height of trajectory and the velocity of their rifles, as, by taking such a point as 80 yards in a range of 150, there is little fear of the velocity or weight of the bullet making any material difference; for, although, strictly speaking, the various bullets may have different culminating points, no ordinary mode of measurement would tell the variation in height of the same bullet if taken a yard or two earlier or later.

One method of calculating the height of trajectories from times ascertained by the chronograph is to take the time at any given point (say, 50 yards), and multiply by the difference between the time at 50 and the time of the full range (say, 150 yards); and the product, multiplied by the drop per second, is taken as the height of the trajectory at 50 yards, or whatever the selected distance may be. I confess, however, I prefer to subtract the drop from the height of angle, although it may be a more cumbersome process; for the former makes the trajectory appear somewhat too low. To show the effect, I will illustrate it by reference to the foregoing table. The highest point of the trajectory would, by this method, be at the point exactly corresponding with half-time of the full range. If we take this half time, and square it, we get one-fourth, and multiplying this by the gravity drop per second, we find the highest point of the trajectory given is exactly one-fourth of the drop in the full range. But, if we look at the angle of elevation, we see that at mid-range (not mid-time) its height is just one-half of the total drop; whereas the time being less than half, the drop up to that point is less than a quarter. If we subtract from the height of angle at half-distance the amount of drop in that distance, the result is that we find the position of the bullet to be higher than the "highest point of the range" as calculated by the method alluded to. This appears to arise from the fact that the line of angle representing the elevation of the gun is a line of mean velocity, whereas, the base line of the angle is a line of variable velocity, and consequently the points of time on the two lines do not coincide. Calculated by the method in question, the greatest height of trajectory, as based on half-time, would be, for the 260grs. bullet 3·48in., and for the 360grs. bullet 4·97in. Accordingly the results would not accord satisfactorily with the foregoing table, nor with calculations worked out on the basis now to be described.

### MODE OF CALCULATING VELOCITY FROM BULLET MARKS ON TARGET.

Express rifles are commonly sighted for 150 yards, and this range will therefore be very suitable for the experiment. Mark a horizontal line on a target or sheet of paper, and, having measured a distance of 80 yards from this target, fire half a dozen shots, aiming at the line, with the rifle sighted for 150 yards.

Measure each shot separately, from the centre of the bullet-mark to the centre of the horizontal line, and calculate the average of the whole. If the shooting be pretty even, Express bullets, according to their weight and velocity, should average from about 4in. to 5½in. above the horizontal line on the target, and this will represent the height of the trajectory above the line of aim. Military bullets would be considerably higher.

To the height thus obtained, add $\frac{8}{16}$ths of the height of the sight from the centre of the bore, and you obtain the height of trajectory without sight allowance. Multiply this by the square of 15 (or 225) and divide by the square of 8 (or 64) and you obtain the same result as dividing by the square of $\frac{80}{150}$, which represents the proportionate part of the range. This gives you the total bullet-drop in 150 yards. Very nearly the same result is obtained by merely multiplying by $3\frac{1}{2}$, as dividing by the square of $\frac{80}{150}$ is similar in effect to multiplying by 3·516.

Take the total drop in inches and fractions, divide by 193·145 (the number of inches fall by force of gravity in one second), and the square root of the quotient gives the time of flight of the bullet for 150 yards—a fraction of a second.

Divide 450 feet (150 yards) by this fraction of a second, and the mean velocity is ascertained. The mean velocity for 150 yards is also the actual speed of the bullet at half the distance, or 75 yards.

Then, having ascertained the factor of resistance, or $\frac{d}{w}$ of the bullet (by squaring diameter, dividing by grains of weight, and multiplying by 7000 to turn it into pounds or fractions of a pound), multiply the 225 feet (or 75 yards) by this factor of resistance, and you obtain a number which, added to a "Space number" in Bashforth's table corresponding to the velocity at half-distance, will give a second number which, on again referring to Bashforth's table, will show the muzzle velocity.

At the time of the recent *Field* trial of rifles at Putney I endeavoured, by this method, to ascertain the approximate velocities from the bullet marks on the paper screens; but, as the rifles were fired from a machine rest, and they were levelled from the bore, there was no need to make any allowance for height of sight. Having ascertained from the screens the average height of the bullet-marks of four rifles, I worked out the estimated velocities. Two of these were only 1 ft.-sec. each different from the velocities obtained by the chronograph; the other two were fully 50 ft.-sec. out. The getting so very close in two instances I take to be a mere "fluke;" but in the other two I consider the difference would have been less, except for some divergences of the bullets arising from their contact with previous paper screens.

Now, it must be admitted that the above-mentioned process of multiplying and squaring fractions is rather troublesome; and so is that of finding out the distance of the highest point of the trajectory from the muzzle of the gun. But very similar results may be obtained by a simpler empirical process, which may be thus described:—

To find the *distance* of the highest point of trajectory, multiply the length of range by the fraction ·52, if the range is 100 yards, and add ·01 to the fraction for every additional 50 yards.

To find the *height* of the trajectory at this highest point, multiply the drop in the full range by the fraction ·28, if the range is 100 yards, and add ·01 to the fraction for every additional 50 yards.

The respective multiples will thus be as follows:

| Length of Range. | Greatest Height of Trajectory. | |
|---|---|---|
| | Multiple of Distance. | Multiple of Drop. |
| 100 yards | ·52 | ·28 |
| 150 „ | ·53 | ·29 |
| 200 „ | ·54 | ·30 |
| 250 „ | ·55 | ·31 |
| 300 „ | ·56 | ·32 |
| 350 „ | ·57 | ·33 |
| 400 „ | ·58 | ·34 |
| 450 „ | ·59 | ·35 |
| 500 „ | ·60 | ·36 |

These will apply approximately to all express rifles; but light bullets with very high velocities are slightly under-estimated at short ranges and over-estimated at long ranges, and *vice versâ* with heavy bullets and low velocities. Thus, taking 150 yards as the range, and multiplying it by ·53, we get 79·5 yards as the highest point of trajectory. This would be nearly true of the 360gr. bullet with 1600 ft.-sec. muzzle velocity, but rather short for the 260gr. bullet with

2000ft. velocity. We can meet extreme cases, however (if thought necessary), by taking the next point higher or lower; for, if we multiply 150 by ·54 instead of ·53, we get 81, which is just about the highest point of the 260gr. trajectory with 2000 ft.-sec. initial speed.

In similar fashion, if we know that the drop of the 360gr. bullet, with 1600 ft.-sec. muzzle velocity, is 38 inches in 200 yards, we multiply 38 by ·30 and get 11·4in. as the greatest height of trajectory; and this is sufficiently correct. In 500 yards, the result would be too high.

### EFFECT OF TEMPERATURE AND MOISTURE.

Hitherto all that has been said about the resistance of the atmosphere has had reference to the effect produced when the air is of the normal weight, or when there is a fall in the barometer alone taken into account. Professor Bashforth's tables, lately given, are calculated on the supposition that the weight of a cubic foot of air is 534·22 grains, which is the weight of dry air at a temperature of 62° F., under a pressure of 30 inches of mercury. When the barometer rises above or falls below 30″, the weight of the air is increased or diminished, and the weight is further affected by the amount of moisture. If one takes into consideration nothing more than the rise or fall in the barometer (as may be done with the ordinary run of mild English weather), the co-efficient of resistance (or $\frac{d^2}{w}$) need only be multiplied by the height of the barometer, and divided by 30, and the rest of the calculation be worked on this basis. If, however, you wish to take temperature and moisture also into account, then it is necessary to ascertain the weight of a cubic foot of the air in which the experiment is carried on, and for that purpose recourse must be had to meteorological tables, such as Mr. Glaisher's, if strict accuracy is required; but a close approximation may be obtained by means of the table here given, which will suffice for all practical purposes, and render unnecessary the reprinting of longer tables and giving an explanation of their mode of use. This table, and the remarks appended thereto, are taken from a very interesting article, by Lieut. E. L. Zalinski, of the United States Army, which appeared in an American journal, *Forest and Stream*, of June 21, 1883, a copy of which was sent me by a friend:

TABLE OF WEIGHTS OF AIR, PER CUBIC FOOT, AT DIFFERENT TEMPERATURES, THE BAROMETER BEING AT A HEIGHT OF THIRTY INCHES AND MOISTURE AT 66⅔ PER CENT. OF SATURATION.

| Temperature. | Weight per cubic feet of air in grains. | Mean change of weight for each $\frac{1}{10}$ inch change in height of Barometer. | Mean change of weight for each degree of temperature. | Mean decrease of weight with humidity at saturation (=100). |
|---|---|---|---|---|
| | | Grains. | Grains. | Grains. |
| −30° | 647 | | | |
| −20° | 633 | 2·1 | 1·4 | |
| −10° | 619 | 2·1 | 1·4 | 0·10 |
| 0° | 605 | 2·0 | 1·4 | 0·20 |
| 10° | 592 | 2·0 | 1·3 | 0·35 |
| 20° | 579 | 1·9 | 1·3 | 0·53 |
| 30° | 567 | 1·9 | 1·2 | 0·76 |
| 40° | 555 | 1·8 | 1·2 | 1·03 |
| 50° | 544 | 1·8 | 1·2 | 1·42 |
| 60° | 532 | 1·8 | 1·2 | 1·96 |
| 70° | 521 | 1·7 | 1·2 | 2·66 |
| 80° | 509 | 1·7 | 1·2 | 3·60 |
| 90° | 497 | 1·7 | 1·2 | 4·83 |
| 100° | 485 | 1·6 | 1·2 | 6·50 |
| 110° | 473 | 1·6 | 1·2 | 8·32 |

"It is seen from the above that an average change of 15·5° of temperature is equivalent to one inch height of barometer. At or near sea-level the changes of barometer rarely exceed two-tenths (0·2) of an inch from a mean height of 30in., producing a variation of less than four grains of weight per cubic foot. It is apparent that the probable limits of changes of barometer affect the weight of air so slightly that it may ordinarily be considered as at a height of 30in., or, better, at the average height of any firing locality.

Temperature, however, varying considerably as it may within a single day's firing, and ranging at different seasons from below zero to more than 100° above, effects marked changes in the weight of air, and may not be neglected. It is seen that the weight decreases with rise of temperature.

At Ft. Keogh, Montana, the temperature ranged from —27° in February, 1882, to 109° in August, 1882, a variation of 136°, giving a difference of weight of air of 161grs. per cubic foot.

Moisture reduces weight of air by its elastic force, but the extreme variations produced by this are so inconsiderable, compared with the changes produced by temperature, that ordinarily no great error will result if the weight of the air is taken for a condition of $66\frac{2}{3}$ per cent. for saturation. It will be seen this element decreases the weight most at the higher temperatures."

Fortunately, in these islands we do not run to such extremes as 109° in summer and 27° below zero in winter; and therefore we shall not require to make allowance for temperature and moisture to the full extent mentioned in the above table. As this table is calculated for an amount of moisture equal to two-thirds (or $66\frac{2}{3}$ per cent.) of saturation, and our temperatures do not usually go to great extremes, we will leave moisture out of consideration, and merely pay attention to the barometer and thermometer. Supposing, then, that the barometer stands at 29″ instead of 30″, and the thermometer is at 55°, we find that at 50° the weight of the air is 544 grains; for the other five degrees we deduct five times 1·2, as shown in the fourth column, which reduces the weight to 538; and as the barometer is 1 inch below 30, we deduct also ten times 1·8, as shown in the third column, and consequently get 520 grains as the weight per cubic foot of air. Bashforth's tables are calculated on the basis of 534·22 grains per cubic foot; and, to allow for the difference in weight, the number obtained as the $\frac{d^2}{w}$ of the bullet has to be multiplied by 520 and divided by 534·22, and the result used as the basis for calculation of the experiments carried out under this condition of the atmosphere.

Lieut. Zalinski's paper also contains a number of calculations on the effect of temperature on air-resistance, but as they apply almost exclusively to the American military rifle, it has not been thought necessary to quote them here. A second paper, in continuation of the subject, was announced, but I not know whether it has been published. Other articles, by various writers have, I understand, also appeared in American journals, touching on the same subject, but unfortunately I have not had an opportunity of perusing them. It seems certain, however, from the number of articles published, that our American cousins pay much more attention to such matters than do the sportsmen of these islands.

## TRAJECTORIES OF LARGE-BORES.

The previous remarks have chiefly had reference to the trajectories of Express bullets. For the calculation of the trajectories of spherical balls the foregoing set of tables would be useless, as the amount of air-resistance with spherical shot is entirely different at all velocities. It would occupy too much space to insert here another set of tables similar in dimensions to those just given, and anyone who wishes to have recourse to them must therefore be referred either to Professor Bashforth's treatise, or to the blue-book containing his first report, already alluded to. But a few particulars, from notes relative to the large-bores at Messrs. Holland's trial in 1879, may be of interest, more especially as no chronograph velocities were taken with the large-bores shot at the *Field* trial of 1883.

In his book on the "Sporting Rifle," already alluded to on page 9, Capt. Forsyth gave the trajectory of a 14-bore rifle which had much pleased him. Its "point-blank range" with spherical ball was stated by the author to be about 60 yards with 3drs., 85 yards with 4drs., and 100 yards with 5drs.

The height of the trajectory at different points of the range was given as follows:

| | 25yds. | | 50yds. | | 75yds. | | 100yds. |
|---|---|---|---|---|---|---|---|
| 14-bore ................. | 1in. | ...... | 2$\frac{5}{8}$in. | ...... | 2$\frac{3}{8}$in. | ...... | 0 |

These measurements will serve as a basis for comparison with the trajectories of the rifles of 12-bore and upwards that were tried in the course of Messrs. Holland's experiments.

It may be as well, however, first to insert Capt. Forsyth's definition of "point-blank range." He says (the italics are his own): "I define the point-blank of the sporting rifle to be, *that distance up to which a shot may be taken at any object without allowing anything for the rise or fall of the projectile.* A rise or fall of 1 inch will not require any allowance to be made even in the finest shooting that ever occurs in actual sport; therefore, this amount of rise and fall will regulate the length of the point-blank range." A rise or fall of 1 inch would be equivalent to a rise of 1$\frac{1}{2}$ inch above the line of sight at mid-range without allowing for fall.

Let us now take 100 yards as the range of Messrs. Holland's rifles, and supposing the 12-bore to be sighted for the largest charge (the bullet dropping 9 inches in 100 yards), the rise and fall of the bullets, with four different charges, was estimated as follows:

TRAJECTORIES OF 12-BORE RIFLE, SIGHTED FOR 9IN. FALL IN 100 YARDS.

| | 25yds. | | 50yds. | | 75yds. | | 100yds. |
|---|---|---|---|---|---|---|---|
| 4drs.......... | 1·5in. | ...... | 1·5in. | ...... | —0·7in. | ...... | —5·3in. |
| 5drs.......... | 1·7 | ...... | 2·0 | ...... | 0·6 | ...... | —3·0 |
| 6drs.......... | 1·8 | ...... | 2·4 | ...... | 1·6 | ...... | —1·0 |
| 7drs.......... | 1·9 | ...... | 2·6 | ...... | 2·1 | ...... | 0 |

With the same elevation, the bullet fired with the smallest charge falls below the line of aim before it has gone quite 75 yards, and, as the slowest bullet drops most in equal distances, the height of the trajectory is consequently less than with the faster bullets. If, however, the elevation be increased, so as to make each bullet strike on the line of aim at 100 yards, the trajectory is highest with the slowest bullet, as about one-fourth of the former drop below the line is now added to the height at the first point, half at the second, and three-quarters at the third; for example:

TRAJECTORIES OF 12-BORE RIFLE, ELEVATED FOR DIFFERENT CHARGES.

| | 25yds. | 50yds. | 75yds. | 100yds. |
|---|---|---|---|---|
| 4drs. | 2·9in. | 4·2in. | 3·4in. | 0 |
| 5drs. | 2·4 | 3·5 | 2·8 | 0 |
| 6drs. | 2·0 | 2·9 | 2·4 | 0 |
| 7drs. | 1·8 | 2·6 | 2·1 | 0 |

The trajectory of Capt. Forsyth's rifle would thus be intermediate between the last two on the list, except as regards the 25 yards, which appears to be very low as compared with the figures just given; but these calculations of Messrs. Holland's trajectories were made from the axis of the bore, without any allowance for the height of the front sight; whereas Capt. Forsyth's trajectories were ascertained by measurements from shots fired at paper screens, aim being taken from the sight in the usual way. What was the height of the sight on Capt. Forsyth's rifle I do not know, but probably it was something more than half an inch above the axis of the bore. Taking it, however, at half an inch, this would lower the trajectory by $\frac{3}{8}$in. at 25 yards, $\frac{2}{8}$in. at 50 yards, and $\frac{1}{8}$in. at 75 yards. This would bring them much nearer together; and possibly some little further difference may have been caused by the bullet striking several paper screens in succession, as such appears to have been the case with the paper screens used at the Putney trials.

The trajectories of the larger rifles in Messrs. Holland's trial did not differ very greatly from that of the 12-bore with the largest charge, but were lowest with the heaviest bullets. Supposing in each case the bullet to strike on the line of aim at 100 yards, the following would be the trajectories.

### TRAJECTORIES OF THE LARGE-BORES.

| | 25yds. | 50yds. | 75yds. | 100yds. |
|---|---|---|---|---|
| 10-bore, 8drs. | 1·9in. | 2·7in. | 2·2in. | 0 |
| 8-bore, 9drs. | 2·0 | 2·9 | 2·3 | 0 |
| Ditto, 10drs. | 1·8 | 2·5 | 2·1 | 0 |
| 4-bore, 14drs. | 1·7 | 2·4 | 1·9 | 0 |

With regard to the "point-blank range," I think that, with spherical-ball rifles, the distance should not be much more than the bullet would travel in the fifth of a second. This would allow for a drop of about 8in., and the trajectory would be very similar to that of the 4-bore just given. Adopting this time limit, the "point-blank range" of the 12-bore rifle above mentioned would be about 75 yards with 4drs., 83 yards with 5drs., 90 yards with 6drs., and 95 yards with 7drs.; while the 10-bore and 8-bore (with 10drs.) would be about 93 yards, and the 4-bore about 97. With the Express rifle, however, as the bullet loses its velocity less rapidly, and the trajectory is consequently flatter, the time limit need not be so short.

In making use of the term "point-blank," in the foregoing remarks, I do so in consideration of the fact that it is commonly used by sportsmen, and in order to show in what sense it is employed by an acknowledged authority on sporting rifles. Capt. Forsyth's definition, however, is by no means of universal acceptation; and, indeed, no definition is generally accepted. It was stated in the daily press last year that a newly-invented rifle had a point-blank range of 900 yards! General Lefroy recommended, some years ago, that the use of the term should be abandoned; and such has been done of late in military books.

### TRAJECTORY OF MATCH RIFLES.

As to match rifles, the following article, from a great authority on the subject, is so complete, that it is desirable to reprint it in full. It originally appeared in the New York *Spirit of the Times* of April 13, 1878.

## TRAJECTORY OF THE MODERN MATCH RIFLE.

### By W. E. METFORD, C.E.

In treating of this very interesting branch of gunnery, the writer will not refer to any older views based on the spherical bullet, for air resistance with such a bullet is so heavy that practically long range was ever out of the question.

When the use of a solid bolt in the place of a short conoidal bullet, and about 2¼ diameters, was introduced, gunners began to get to ranges which naturally brought the question of trajectory prominently forward. Since then Sir Joseph Whitworth increased the length of the rifle bullet to nearly its present amount, and it appears that gunners have now arrived to a final proportion of diameter to length of about 1 to 3, with a weight of from 540 to 550 grains. With this proportion of bullet all the modern shooting is being performed; and it is with the trajectory of this bullet, therefore, that the writer will deal.

Before, however, entering into the trajectory of the present bullet, it may be as well to point out that, even with such trajectories as given by the old English Enfield musket, there was none of that very rapid sharpening of the curve of the trajectory which it has been the fashion of writers to pourtray in their books; for instance, the Enfield, when loaded with the cartridges best adapted to it, had its culminating point but just 50 yards beyond the half way for the 1000 yards, and the slopes of its falling into the target were, for the longer ranges, with the very best fresh cartridges, as follows:—

| | | | | | |
|---|---|---|---|---|---|
| 600 yds., | 1 foot in about | 27 feet. | 900 yds., | 1 foot in about | 13½ feet. |
| 700 ,, | 1 ,, | 20½ ,, | 1000 ,, | 1 ,, | 11 ,, |
| 800 ,, | 1 ,, | 16½ , | | | |

And its angles were, with such cartridges, as follows:—

| | | | |
|---|---|---|---|
| 100 yards, about ......... | 12′ 9″ | 600 yards, about ......... | 1° 40′ 3″ |
| 200 ,, ......... | 27′ 2″ | 700 ,, ......... | 2° 3′ 4″ |
| 300 ,, ......... | 42′ 9″ | 800 ,, ......... | 2° 29′ 0″ |
| 400 ,, ......... | 1° 0′ 2″ | 900 ,, ......... | 2° 57′ 2″ |
| 500 ,, ......... | 1° 19′ 2″ | 1000 ,, ......... | 3° 28′ 4″ |

and this trajectory was produced with a bluff, short wood-plugged bullet of 530 grains and 70 grains of powder, and having a computed initial speed of about 1160 feet per second.

The match rifle—which the writer takes to be the fullest expression of a first-rate modern long-range small arm—when charged with 90 grains of the English powder of Curtis and Harvey's No. 5 or No. 6,* will drive a 540 grains bullet at the rate of about 1400 feet per second out of its muzzle.

In treating of trajectory, it would appear to be the best way, first, to point out that, if there existed no air, the bullet, fired at any given angle from the horizontal would fall into the target at its initial or muzzle speed,† and the angle of the inclination of the fall in of the bullet on the target would be precisely equal to that of the inclination of the bullet's path in its issue from the rifle's muzzle; and, secondly, to point out that the curve of the bullet's path would be a parabola of which the apex would be the half-way point. Now, when the curve happens to be a very short piece of a very flat parabola, it may be held to be, for all practical purposes, equal to a short piece of a very large circle;‡ and, again, for curves where the height of the trajectory bears a small proportion to the length of the arc, it may be taken as sufficiently correct that the distance round the arc is equal to the length of the straight or eye line. For instance, the difference, as computed, is about a foot, with the flat curves of the modern rifles, for the 1000 yards range.

If the above positions be granted, then, where there is no air existing, we may use the problem of Euclid III. XX., which indirectly proves that equal portions of a circular curve will give angles equal to each other from any position on the curve itself. For example, to put the point into a practical form, let a man, on a piece of level ground, put up a theodolite (an instrument many readers will know is for setting off, and also for taking angles) exactly over a peg, and having set out, with the aid of assistants, a truly straight line for 1000 yards, at each 100 yards let him drive in a peg truly in the line. Let him then set off from this line any given angle, such as, say $8\frac{1}{2}'$, by the aid of the instrument, and get his assistants to measure out 100 yards alongside the straight line already laid out; let a pole be ranged by the aid of the cross wires in the telescope of the theodolite at this 100 yards and left there (this would be a position about nine inches from the first peg on the straight line already set out); let the same thing be done again, that is, another 8½′, or in toto 17′ of angle, be set off, and another 100 yards measured and poled (this would be a position of 35½ inches from the second peg on the straight line), and so proceed, adding the 8½′ each time to the angle and putting up a pole, and so on to 1000 yards. The operator would then have set out a truly circular curve together with its tangent.

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* With the Hazard powder (American) about 106 grs. are required to attain this speed.

† In the ascent to its culminating point the bullet would lose speed, but this loss would be exactly balanced by the gain in the descent from this highest point of the trajectory. In cases such as the modern rifle's bullets give, this loss and gain may be, for the ranges in use, safely ignored. The writer will, throughout this article, assume the 1000 yards to be a true plane.

‡ In all that concerns the curves here treated of they would coincide within some fractions of an inch.

He would also find, if he measured, from the last pole on this curve in a straight line back to the theodolite, in fact on the chord of the arc, that the distance would be 999⅔ yards, that is if the measurements were made throughout with such an unstretchable thing as a steel tape, and all very carefully indeed; and he would also have the natural curve that a match rifle bullet would make if the curve could be put in a horizontal position, and if the bullet had been projected *into a vacuum*. If this is the case, then the actual difference or angle between this and the actual curve is due to the air resistance retarding the speed of the bullet, and thus giving more time for gravity to act, and so coercing the bullet into making not only a coarser curve, but a curve rapidly altering its pitch. For instance, the writer finds, as already stated, that where the speed is 1400 feet per second, and where about 8½′ of angle would in vacuo be the angle of elevation for 100 yards, and 8½′ × 10′ would be the angle for 1000 yards, the radius of such a curve would be 20,222 yards, or 11½ miles, whereas, as matters stand, the radius of any part of the actual curve would be:

| | | |
|---|---|---|
| At 50 | yds. (or the mean between 0 yds. and 100 yds.), about | 18,600 yds. |
| At 150 | ,, | 16,000 |
| At 250 | ,, | 14,040 |
| At 350 | ,, | 12,510 |
| At 450 | ,, | 11,270 |
| At 550 | ,, | 10,260 |
| At 650 | ,, | 9,420 |
| At 750 | ,, | 8,700 |
| At 850 | ,, | 8,090 |
| At 950 | ,, | 7,560 |
| At 1050 | ,, | 7,090 |

Now, all this is to be easily computed from the actual angles as ascertained—first, by much shooting in good weather, and, secondly, by computing a table of angles which will fit fairly accurately the mean of such shooting, of which more further on.

The sights of the writer's rifles have ever been divided in terms of the great circle—that is, instead of putting on an arbitrary scale, where the angular value in rise, usually the hundredth of an inch, varied as the distance between the sights varied, a scale was put on of such a character that, whatever the distance between the sights might happen to be, the dividing of the scale should be such that, first, it should invariably give but one angular value, and, secondly, it should be that same angular value which has been universally recognised as the standard for all angle-taking instruments; thus the rifleman would be, in conversing about his sights, speaking a language universally accepted by scientific men.

Such a system involved, of course, giving up a simple value per inch, as, for example, the one-hundreth of an inch, or one inch, and also involved cutting the scales in a definite relation to the distance between the two sights, or what is called the radius. The reader will now perceive that his sights are in fact neither more nor less than a piece of an extremely large theodolite or angle-taking instrument,* and that he therefore is able to ascertain with it the actual angles of the projecting instrument to which it is attached—that is, the barrel.

It has been the custom for gunners to ascertain their trajectories by erecting screens, covered with tissue paper, at intervals along the track of the bullet. This method, available without much trouble for short ranges, becomes difficult with the larger ranges. It is open to objection, too, that the bullet, in passing through any substance, however thin, not only receives a check, but also is liable to the possibility of deflection. The first objection is the most important, and the time alone it takes makes it objectionable.

But why should any such trouble be thought necessary when, with the modern sights—actually a perfect bit of a very large theodolite—the entire path of the bullet can be calculated with the most perfect certainty and rapidity. Or, if a gunner dislikes figures, he may, as has been already pointed out, lay the entire curve out on a flat meadow, either with a good theodolite, or even with the rifle sights themselves, with the rifle laid horizontally and rigidly fixed. He may do exactly as the writer has already pourtrayed, except that, instead of setting off 8½′, he sets off the table at angles of his rifle. He will thus have his trajectory laid flat on the turf. He can ascertain the trajectory by actual measurement, for any range and at any part of the range. He can, if he has not 1000 yards of turf at hand, do it to say a half, third, or quarter scale, or even a tenth or twelfth scales, if only 100 yards are available, and multiply his values by twice, three, four, ten, or twelve times, as may be, to procure actual values; and with regard to, say, a twelfth scale, there is the convenience that the operator could lay out the entire curve in less than 100 yards; and, with his offset rod divided to inches and twelfths, he would be able, without much walking, to ascertain his values at once, substituting feet for inches.

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* The circles of all angle-taking instruments, as is well known, are divided into 360 degrees, and each degree into 60 minutes, which would give 21,600 minutes for the whole circle. The value is given in minutes, as, for small angles, it is sometimes preferred to have their values stated in minutes, instead of degrees and minutes. For instance, the 1000 yard angle can be expressed in degrees and minutes—thus, 2° 15′, or in minutes alone, 135′.

If, however, a gunner desires to ascertain his trajectory heights by computation—and of course this is the most accurate and quickest method, for he will escape the chance of errors in setting the lines out (a process requiring care and skill)—he will proceed thus: Let it be supposed that the rifleman desires to ascertain the path the bullet makes for 1000 yards. The zero of the scale of his rear sights, divided to degrees and minutes of the great circle, has been ascertained to be correct, by shooting at, say, 12 yards,* with the Vernier at zero, and seeing that the bullet centre is just as much below the centre of the small dot he shoots at, as the eye line is above the axis of bore, plus the one-eighth of an inch which must be added for gravity pull acting during the time the bullet is travelling the 12 yards. Let his rifle, under this condition, be assumed to give the following angles:

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 | yards | 9′ | 600 | yards | 1° 09′ | or 69′ |
| 200 | ” | 19′ | 700 | ” | 1° 24′ | ” 84′ |
| 300 | ” | 30′ | 800 | ” | 1° 40′ | ” 100′ |
| 400 | ” | 42′ | 900 | ” | 1° 57′ | ” 117′ |
| 500 | ” | 55′ | 1000 | .. | 2° 15′ | .. 135′ |

Now, when shooting at 1000 yards, the bore of the rifle, at the instant the bullet is passing the muzzle, will have to point at an angle of 2° 15′ (some persons prefer to omit the use of degrees, and record the angles in minutes only), or 135′ above the centre of the bull's-eye.

This is the first position. Now let a case be assumed. Say it is required to compute the heights of the trajectory for every hundred yards along the whole range to 1000 yards, beginning at the position of the first 100 yards. On examining the table, it is clear that the bullet (neglecting the little difference already referred to, caused by the eye line and the bore line not being quite coincident),* had there been no gravity pull, would have kept along the 135′ line; but gravity has had time to pull the bullet down 9′ by the time it has got to the first 100 yards, therefore the bullet would actually pass below the 135′ line this 9′, or 126′ above the eye line. And because at 100 yards 1′ equals 0·0873 of one foot,† therefore 0·0873 × 126 ft., which equals 10·99 ft., is the height the bullet passes at 100 yards above the eye line.

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* Twelve yards is a convenient distance, for reasons stated further on.

To repeat the process, substituting the different distances along the ranges for the 100 yards :—

| Yards. | | | | | Feet. | | Times. | | Feet. |
|---|---|---|---|---|---|---|---|---|---|
| 200 ..................... | 135′ | − | 19′ | × | 0·0873 | × | 2 | = | 20·2 |
| 300 ..................... | 135′ | − | 30′ | × | 0·0873 | × | 3 | = | 28·1 |
| 400 ..................... | 135′ | − | 42′ | × | 0·0873 | × | 4 | = | 32·4 |
| 500 ..................... | 135′ | − | 55′ | × | 0·0873 | × | 5 | = | 34·9 |
| 600 ..................... | 135′ | − | 69′ | × | 0·0873 | × | 6 | = | 34·5 |
| 700 ..................... | 135′ | − | 84′ | × | 0·0873 | × | 7 | = | 31·1 |
| 800 ..................... | 135′ | − | 100′ | × | 0·0873 | × | 8 | = | 24·4 |
| 900 ..................... | 135′ | − | 117′ | × | 0·0873 | × | 9 | = | 14·1 |
| 1000 ..................... | 135′ | − | 135′ | × | 0·0873 | × | 10 | = | 0·0 |

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* To be very accurate, to these angles should be added the angular value which the fact of the eye line being above the bore line demands. This would give for 100 yards 9′ + about 1′, for 200 yards, 19′ + $\frac{1}{2}$′, and for 300 yards 30′ + $\frac{1}{3}$′, and so on.

† Should the computer prefer the values to be in inches, he would have to substitute 1·0472in. for 0·0873ft., for the value of 1′ of angle at 100 yards. It has been already stated there are 21,600′ in the circle; the value of 1·0472in., or 0·0873ft. is, therefore, computed as follows: What is the value of 1′ of angle at 100 yards in actual measurement? There are 21,600′ in the circle, and the radius is 100 yards; all, therefore, that has to be done is to find the feet measurement of the circumference of this circle, and divide by 21,600. The ratio of circle and radius being 6·2832, these last figures of the ratio must be multiplied by 100. This equals 628·32 yards or 1884·96ft., and is the length of the circle round; and 1884·96 ÷ 21,600′ = 0·08726ft. per 1′, &c., and if inches are preferred, then these last figures multiplied by 12 will give the value of 1′ of angle, or in inches 1·0472 nearly. Call it, when feet are required, 0·0873, and when inches are required 1·047. Of course, unless great accuracy is required, 0·087 and 1·05 will give close results.

For rough computation, 1in. for 1′ at 100 yards will be sufficiently near to give results. To be accurate, 1in. equals 1′ at 95·49 yards. The same values can be computed with a table of sines. And here it is as well to bring to the recollection of those who are conversant with such tables that, for small arcs, say to 4°, it may be reckoned with perfect safety that the arcs can be practically taken as equal to either the chord, sine, or tangent.

Here the last column will represent the exact heights of the curve at every 100 yards along the range from the line of sights or eye line.*

Again, let it be required to find the highest point in the curve.

By inspecting the last column it will be seen at once that this point must be somewhere between 500 and 600 yards, and probably between 500 and 550 yards. It shall be assumed that 540 yards will be the place. Now the angle for 540 yards must be computed. At 500 yards it is 55′, and at 600 yards it is 69′, or a difference of 14′. It is not strictly correct to divide proportionately by the distance, but as it only involves an error of one-eighth of a minute at the half way, it may be done without fear. If this be done, the angle at 540 yards will be 60′ 6″, say 60′ 5″, which is really more correct. Thus, for 540 yards, 135′— 60′ 5″ × the 0·0873 × 5·4 times = 35·073 feet. The question now comes, is this the highest point; if not, which side of 540 yards is it? The thing, therefore, will be to try one side of 540. Let 535 yards be taken. For this distance 59′·9 will be the angle. Then for 535 yards it will be 135′— 59′·9 × 0·0873 × 5·35 times = 35·0758 feet.

Clearly this is a very small trifle higher than 35·073 feet, and thus the point is between 535 yards and 540 yards, and probably near enough for general purposes.† If it should be desired to determine it closer, each yard could be computed—actually the place is between 535 and 536 yards—thus the entire trajectory values, yard by yard, if necessary, can be computed from the sight elevations with an accuracy and a certainty far surpassing screen experiments, which are subject to the variations of each shot, as well as to the drawbacks already mentioned, and also with a freedom from the errors which will arise even with experienced users of the theodolite. The latter plan, it is true, places the whole affair, especially if it be done on a tenth, or some such scale, as it were before the eyes, at one single grasp; but, excepting this,

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* It will easily be understood that if it be desired to compute the heights for any other trajectory, as, say, for 600 yards, all that is necessary will be to substitute for 135′ the 600 yards angle of 69′.

† To give an idea of the flatness of the curves, this short table is appended:

| | |
|---|---|
| 534 yards | 35·07552 |
| 535 yards | 35·07583 |
| 536 yards | 35·07589 |
| 537 yards | 35·07571 |
| 538 yards | 35·07523 |
| 539 yards | 35·07456 |
| 540 yards | 35·07364 |

From this it will be seen how many figures of decimals it requires to detect the exact point.

calculation is by far the better plan where very accurate values are required.*

With regard to the computations, it will be seen that simple arithmetic is sufficient to insure perfect results, and those who are conversant with that very simple thing, the slide rule, may get close enough results to serve every common purpose.

With regard to the table of angles and their method of construction, the first thing the writer has always done is to shoot his rifle at 12 yards (a mere convenience as regards the distance—the 1′ of angle at that distance is one-eighth of an inch, which all foot rules give.) He shoots at a row of dots, say five, first one shot, with the sight at a guess position—the sight not being divided. The shot ought to strike the difference between the axis of bore and the eye, or sight line, plus the drop by gravity, which is an eighth of an inch for twelve yards, when the speed is about 1400 feet per second. If it does not strike this much below the dot—and the chances are it will not—then the error between the place where the bullet should strike, and where it actually does, is measured in eighths; and as eighths are equal to minutes, the slide carrying the aperture is screwed up or down, as the case requires, the number of minutes wanted to make the bullet strike where it should—which can be done by compasses stepping off the amount from an already divided sight borrowed from a similar rifle. After a shot or two to verify, a pencil line is struck across, and the divisions and Vernier cut. The Vernier should have the power of shifting 10′ or more. The rifleman will verify the truth of the Vernier position, of course. With the sight so set, the rifleman shoots in all weathers at enough ranges along the 1000 yards to enable him to get the angles on which he may eventually base his tables. 200, 500, 800, 900, and 1000 yards would be enough. If possible, say ten shots at each range should be made in one day. Now, it is clear, from what has been said, that as the bullet flies along, the resistance of the air checks its speed, and, therefore, gives more and more time than if there was a vacuum for gravity to act. The curve must therefore get coarser and coarser, and the angle more full, for every hundred yards; and that fullness of angle will decrease in some definite way, and not sometimes faster and sometimes slower.

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* Any man accustomed to make very accurate drawings could plot the curve; but it would be better to plot it from the calculated heights than to depend on even the very best protractor—the angles are too fine. A scale of 100 yards to the foot, using a 30 scale, would be found convenient.

This increase, too, will depend for its value not only on the mass, but on the proportion of the diameter to the length of the bullet, &c., also on its speed.

Fortunately the increase of the angle for each 100 yards for the match rifle is so exceedingly nearly one minute of angle, that if a minute be taken to represent the air retardations no error of any possible moment will obtain.

All that remains to be done is to hit on some starting angular value, which, with the additional minute for extra value due to air resistance increasing the time gravity has to act, will fairly fit the mean of observation throughout.

Now this angle which is wanted may be really got at through the speed. The writer possesses a ballistic pendulum, and is able with it to ascertain this speed by the well known gravity formula (fall = 193 inches × time$^2$)* and reducing it to angular value. At the best speed it comes out that it is over 8′—call it 8′; and, as the retardation equals, the writer finds, all but 1′, this makes 9′.

And thus the scale is built as follows:—

| Yards. | | Diff. | Diff. | Yards. | | Diff. | Diff. |
|---|---|---|---|---|---|---|---|
| 0 | 0′ | — | – | 700 | 1° 24′ | 15′ | 1′ |
| 100 | 9′ | 9′ | – | 800 | 1° 40′ | 16′ | 1′ |
| 200 | 19′ | 10′ | 1′ | 900 | 1° 57′ | 17′ | 1′ |
| 300 | 30′ | 11′ | 1′ | 1000 | 2° 15′ | 18′ | 1′ |
| 400 | 42′ | 12′ | 1′ | 1100 | 2° 34′ | 19′ | 1′ |
| 500 | 55′ | 13′ | 1′ | 1200 | 2° 54′ | 20′ | 1′ |
| 600 | 1° 9′ | 14′ | 1′ | | | | |

This scale, which may be called A., is, the writer finds, available for weather giving the flattest trajectory; but he also has scales B. and C. for weather not so favourable. There is, too, some slight difference in rifles, and in muzzle-loaders especially, when a large nipple-hole will let more gas escape than usual. Powder, again, varies a rifle.

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* Fall equals 193 inches × square of time. Practically applied it would be so. Say 1420 feet per second initial speed of bullet, what is the fall due to gravity at 100 yards? 100 yards = 300 feet; then as 1420 feet is to 300 feet, so is 1 second of time to 0·2113 nearly seconds of time; that is, this bullet would, in vacuo, have passed over the 100 yards in 0·2113 seconds. ·2113 × ·2113 = ·04463, etc., and that multiplied by 193 = 8·614 inches, which at 100 yards will, at 1·047 inches to the minute, give 8·22 minutes.

They are as follows: *

| Yards. | A | Diff. | B | Diff. | C | Diff. |
|---|---|---|---|---|---|---|
| 100 | 9′ | — | 9¼′ | — | 9½′ | — |
| 200 | 19′ | 10′ | 19½′ | 10¼′ | 20′ | 10½′ |
| 300 | 30′ | 11′ | 30¾′ | 11¼′ | 31½′ | 11½′ |
| 400 | 42′ | 12′ | 43′ | 12¼′ | 44′ | 12½′ |
| 500 | 55′ | 13′ | 56¼′ | 13¼′ | 57½′ | 13½′ |
| 600 | 1° 9′ | 14′ | 1° 10½′ | 14¼′ | 1° 12′ | 14½′ |
| 700 | 1° 24′ | 15′ | 1° 25¾′ | 15¼′ | 1° 27½′ | 15½′ |
| 800 | 1° 40′ | 16′ | 1° 42′ | 16¼′ | 1° 44′ | 16½′ |
| 900 | 1° 57′ | 17′ | 1° 59¼′ | 17¼′ | 2° 1½′ | 17½′ |
| 1000 | 2° 15′ | 18′ | 2° 17½′ | 18¼′ | 2° 20′ | 18½′ |
| 1100 | 2° 34′ | 19′ | 2° 36¾′ | 19¼′ | 2° 39½′ | 19½′ |
| 1200 | 2° 54′ | 20′ | 2° 57′ | 20¼′ | 3° 0′ | 20½′ |

The writer here points out that, in the construction of the scales B. and C., properly the value 1′ should alone be altered if it be the alteration of air resistance only which is the cause of the alteration of elevation for the same range; whereas he has kept to the 1′ and reckoned as if the initial speed alone had altered. But the fact is that, being desirous to keep to angles not involving endless decimals, he found he could assume an alteration† in the initial speed of a trifling amount, and still no error of any practical value for such ranges as are shot at would arise. In fact, the value of the 1′, slightly too favourable for B. and C., would balance, for these ranges, the error introduced into the speed.

There is a further item in this interesting branch of gunnery to be considered, and that is the loss of initial speed per 100 yards, due to air retardation.

There are difficulties attending the solving of this problem.

If, while the air offered resistance to the forward flight of the bullet, it offered none to its fall, the problem would be easy; but not only does it offer resistance, but this fact has been brought to light, that a body falling in undisturbed air will act differently from what it would in disturbed air.

A body falling, and having at the same time no forward movement, will, as it falls, pack the air under it, and so disturb before it actually gets to it, whereas a body, with a forward movement, such as a rifle bullet, will enter into new and therefore undisturbed air.

The writer's ballistic pendulum unfortunately has always been in a position not to be available for the actual values to be ascer-

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* Scale A. is again entered, so that the difference may be seen without a back reference.

† Such an alteration of speed can, indeed, occur.

tained; he hopes, however, to be able to rearrange its position, and accomplish this, but he computes that, taking the A. table of angles as a basis, and about 1400 feet per second as the initial speed, as it in fact is, the loss of speed will be represented by the following table, as calculated from those angles. Nevertheless this must be said, that it is a computation alone, and on a certain assumption which involves a possibility of error.

The writer, therefore, only gives the table for what it is worth, for he has a strong belief, which it is hoped will be soon verified by actual ballistic experiments, that the loss is not so great as the table gives.

| Distance. | | Velocity. | | Distance. | | Velocity.* | |
|---|---|---|---|---|---|---|---|
| 0 | yards, | 1400 | feet initial speed. | 600 | yards, | 822 | feet initial speed. |
| 100 | „ | 1255 | „ | 700 | „ | 769 | „ |
| 200 | „ | 1136 | „ | 800 | „ | 723 | „ |
| 300 | „ | 1037 | „ | 900 | „ | 682 | „ |
| 400 | „ | 954 | „ | 1000 | „ | 645 | „ |
| 500 | „ | 883 | „ | 1100 | „ | 611 | „ |

There is a very apparent disagreement between two statements made in this paper, the one being that the highest part of the trajectory is not greatly over the half way, and the other that the speed at 1000 yards is not half the initial speed. One would be led to infer, from the great loss of speed, that the highest point would be more like at two-thirds of the range; but it happens that the falling of the bullet by gravity is also checked by the air resistance, and much more heavily than it would be if it fell with its nose pointing downward. In fact, it falls broadside, and thus is in its best attitude for the air resisting its gravity velocity—a fortunate event, for otherwise the trajectory would be far coarser than it now is.

As the position of the bullet opposing its broadside in its gravity fall to the air has been referred to, the writer takes the opportunity of pointing out that, though in vacuo the axis of the bullet would undoubtedly keep parallel to the initial line, in air the axis of the bullet most certainly keeps tangential to the trajectory curve, or so nearly so as to be considered tangential. This fact he has many years since ascertained by direct experiment, and this has since been verified by the Woolwich gunners, by examining the position of the six hundred pounder projectiles in their flight.

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* In this table decimals have been omitted, and the nearest foot the calculations give, taken. The strings of decimals were interminable.

It is rather beside the present position of the loss of initial speed of the match bullet to give tables of the loss of such speed in other bullets, but it may exemplify the massiveness of the air resistance to introduce two tables, computed from actual pendulum experiments with Express bullets.

110 grains powder, Curtis & Harvey, 309 grains bullet, ·451 diameter.

| Yards. | Initial Speed in Feet. |
|---|---|
| 0 | 1913 |
| 25 | 1783 |
| 50 | 1673 |
| 75 | 1578 |
| 100 | 1474 |
| 125 | 1418 |
| 150 | 1347 |
| 175 | 1280 |
| 200 | 1217 |

110 grains powder, Curtis & Harvey, 366 grains bullet, ·451 diameter.

| Yards. | Initial Speed in Feet. |
|---|---|
| 0 | 1765 |
| 25 | 1674 |
| 50 | 1592 |
| 75 | 1518 |
| 100 | 1449 |
| 125 | 1384 |
| 150 | 1323 |
| 175 | 1276 |
| 200 | 1223 |

These bullets it will be at once seen are short in length, in fact they are, as already stated, for Express rifles: it exemplifies the undesirableness of carrying the Express system too far, and also illustrates the point now in treatment.

## APPENDIX.

It may be interesting to those engaged in gunnery to examine the following table, which the writer has drawn up for his general guidance.

It gives for the two columns, the proportions of bullet and powder, and the third column the resulting initial speed.

It is found that these velocities are fairly sound for all usual small arm work, that is, for bores varying very largely, and of the usual length, and also for charges varying very largely. In the length case about eighty times the diameter of bore has been taken: where there is a shorter length a little loss of force will obtain, and *vice versâ.*

In fact, it is a very good general table for breech-loaders, and rather too favourable for muzzle loaders, say about 25 feet per second.

| Lead. | Powder. | Velocity. |
|---|---|---|
| 2 | 1 | 2260 |
| 2½ | 1 | 2000 |
| 3 | 1 | 1850 |
| 3½ | 1 | 1750 |
| 4 | 1 | 1670 |
| 4½ | 1 | 1600 |
| 5 | 1 | 1537 |

| Lead. | Powder. | Velocity. |
|---|---|---|
| 5½ | 1 | 1479 |
| 6 | 1 | 1425 |
| 6½ | 1 | 1374 |
| 7 | 1 | 1326 |
| 7½ | 1 | 1280 |
| 8 | 1 | 1236 |

There is a curious anomaly worth mentioning in relation to the zero of rifles. It is this, that if a thoroughly accurately-made pin-hole plug be entered into the breech end of any rifle, the construction of which permits the eye to see through the barrel, and also an aperture plug be entered at the muzzle; and if the rifle is then pointed, with its sights set to the zero, ascertained by shooting at the 12 yards, at any object, say at 100 yards off, and if then the line of bore be examined—it will be found that there is a very great difference between the two lines, instead of there being only about the inch the eye line is above the bore line.

It happens in all rifles, more or less, and in rifles with the long fore-end, such as military rifles, the removing the fore-end increases the amount considerably.

A rifle, however, having an *extremely* short barrel does not exhibit this anomaly. This peculiarity will develop vertically if the rifle be shot as usual, but horizontally if the rifle be fired horizontally.

The best way to develop this fact is to shoot at such a distance as not to mix up the gravity pull with it, say at 25 yards, when the fall is half an inch only.

The anomaly is no doubt due to the total mass of the rifle being non-coincident with the axis of the bore, and on the jerk of recoil being given (it is like a sharp blow to the rifle, as it happens in less than $\frac{1}{300}$th of a second), the rifle, instead of a true recoil, has imparted to it such a motion as eventually causes the muzzle to jerk up, but of which the first result is to set up a distinct bend of the barrel itself, actually forcing the muzzle *down below* its original line.

It happens that at just about this moment the bullet passes the muzzle, and so it strikes *lower* on the target than if there had been no such action. In fact, it is similar to the action of a fishing-rod, which, if watched while a "strike" is being made, will exhibit, some way three-quarters up, a neutral point, above which the rod will actually move the contrary way for a short time, before the rest of the rod drags this upper part back.

It is easy to comprehend this objection, that the barrel, especially of a match rifle, is too stiff to allow of this; but, first, it is the fact that such a barrel can be easily sprung, even with the two hands, a very eyeable amount out of truth (of course it goes back again), and that the jerk of the kick is in actual fact like the blow of a hammer.

With regard to the improvement of trajectories, the writer does not feel that much more can be done to improve them under the terms of the weights and charges used.

No doubt with a heavier rifle more may be done; for instance, the writer has 15lb. rifles requiring, for 500 yards, 45′; for 1000 yards, 1° 55′; for 1500 yards, 3° 25′; and for 2000 yards, 5° 17′; the initial speed being about 1565 feet per second, but this only because these rifles are "a little bit longer—a little bit broader—a little bit deeper"—than the usual match rifle, which requires about $6\frac{1}{4}^\circ$ at 2000 yards, and the weight of the bullet and powder in proportion.

But the trajectory of the match rifle as it stands is very small. Let the reader contemplate some of the older curves. The English Enfield musket of 1854, for 1000 yards, under its very best conditions, gave $3\frac{1}{2}^\circ$, and with common cartridges $3\frac{3}{4}^\circ$.

The writer's own angles, in 1852, at that range, were worse.

General Jacobs, whose name has been well known in relation to long ranges, was satisfied with very coarse angles; and, though the writer cannot at the moment of writing state what his angles were at 1000 yards, he has found it stated that one of Jacobs' rifles, of $14\frac{1}{2}$lb. weight, especially built for 2000 yards range, required 12° 30′ of elevation for that range, whereas, as has been just stated, even the 10lb. match rifle, with its usual charge, only requires about $6\frac{1}{4}^\circ$. It is probable that the rifle above referred to as requiring 12° 30′ for 2000 yards, would demand over 4° for 1000 yards.

In conclusion it must be admitted that, in studying that branch of gunnery of which this paper treats, a very large field of interest is opened to the rifleman, which, while it cannot but make him a better marksman, must vastly increase his grasp of the subject, and his interest in its higher branches.

# CHAPTER VII.

## RECOIL.

THE recoil of the gun appears to me to consist of two distinct portions, although closely connected; and, for the sake of explicitness, they may be described as the *initial recoil* and the *kick*. The former is a process of gradual development, brief as is the period of action. Until a certain amount of force is generated there can be no movement whatever. As soon, however, as the shot begins to move forward, the gun (unless fixed) would move backward—slowly at first, but with gradually increasing speed as the shot increases in velocity.

On the shot reaching the muzzle, the circumstances undergo a marked change. The "initial recoil" had been gradually increasing as the shot moved faster and faster up the barrel, but now it receives a sudden additional impulse; for hitherto the backward pressure of the gas on the breech had been in great measure counterbalanced by its forward pressure on the projectile; but the counterpoise being lost as the shot leaves the barrel, the full force of the gas takes effect on the breech, and hence it is that the *kick* is so sensibly felt.

During the progress of the shot up the barrel the gas-pressure operating on the breech had not been wholly engaged in producing recoil, because other work had been going on which to some extent counteracted the tendency of the breech to move backward. Thus, breech and barrel virtually form one whole, the breech being no more able to retreat without the barrel than the barrel can run forward without the breech. The force of the gas, however, is exerted, so to speak, in an endeavour to move them in opposite directions; for when the shot is driven forward, it would, by reason of the friction, carry the barrel forward also, just as a tight-fitting mass of tow on a cleaning-rod, on being forced into the bore, will carry the barrel with it unless the latter is firmly held. Accordingly, the force of the powder-gases engaged in pushing back the breech of the gun is diminished in effect by so much of the forward pressure as, in the form of friction, is tending to drive the barrel forward.

Besides this friction, however, which has to be overcome, and the weight of the shot which has to be moved, a considerable proportion of the work to be done by the powder-gases is the expulsion of the column of air in the barrel, which, especially as the shot approaches the muzzle, must offer much more resistance than the shot itself.

When the shot reaches the muzzle of the gun, a sudden relief occurs at one end of the barrel while the gas pressure is still in action at the other. The compressed air is expelled from the barrel, and the frictional resistance and projectile are removed simultaneously; the pressure of the gases being thus exerted unchecked upon the breech, gives a strong additional impulse to the slow-growing initial recoil, and the movement of the gun culminates in the *kick*.

Equal muzzle velocity in shot may be produced by very different powders; and that which, by evolving its gases most rapidly, exerts greatest pressure at first, diminishes soonest in force as the shot moves up the barrel, and exerts least pressure when shot and gun part company. The quick-burning powder would thus give greater initial recoil and less kick. The initial pressure against the shoulder, being in the nature of a comparatively slow push, would in many cases probably have an effect similar to that produced by holding the gun with a very firm grip—the sensation of the kick would be lessened, and, the contrast between the two portions of the recoil being less sharply defined, the shoulder would be relieved from the effect of the kick to a greater extent than could be explained by mere difference of momentum.

It is probable, however, that the increase in the initial recoil, in consequence of the powder being of a rapidly-explosive character, or in consequence of the energy of the powder being enhanced by the increased weight of a heavy projectile as compared with a light one, may have a considerable effect in the accuracy with which a rifle will shoot. This initial recoil may in some measure account, perhaps, for the "jump" or muzzle disturbance in rifles.

## Estimation of Recoil.

One frequently hears that—action and re-action being equal—the velocity of recoil and the velocity of the shot leaving the muzzle must be inversely proportionate to the weight of gun and shot, so that, if the gun be 100 times as heavy as the shot, it will move backward with a hundredth part of the speed with which the projectile moves forward. No doubt such might be the case if projectiles received their impulse at the muzzle of the gun, and started off, without any preliminary progression, like a champagne cork from the mouth of a bottle; but, inasmuch as projectiles have first to make their way through gun-barrels, we must take into consideration the circumstances which arise during the time that the shot is passing from breech to muzzle.

We do not nowadays accept the statement that the more a gun kicks the harder it must shoot, yet that would appear to be a logical sequence of the commonly-accepted doctrine that the momentum of the projectile is equal to the momentum of the gun from which it is fired. This definition appears to be much too limited; for the gun is not fired *in vacuo*, and the air offers resistance, first to the passage of the shot up the barrel, and afterwards to the escape of the gas. A correspondent in the *Field,* some time ago, added to the ordinary definition by saying, "the momentum of the gun is equal to the momentum of the shot, *plus* that of the powder gases as they leave the muzzle." This *plus* is a most necessary rider; for the state of tension of the gas at the instant the shot quits the barrel must have a material influence on the severity of the kick; and where there is a heavy charge of large-grain powder, that is giving off gas copiously up to the very muzzle, the final *kick* produced must be greater than when the chief part of the force is exerted at the breech.

One of the latest novelties in gunnery—a "marsupial gun," as it may be termed—recently brought out in America by Messrs. Lymann and Haskell, seems well adapted to furnish this condition of "giving off gas copiously up to the very muzzle." The gun has four "pouches" under the barrel, each containing powder. The first charge, which is in the ordinary position in the breech, consists of very slow-burning prismatic powder, which gradually sets the shot in motion. When it has thus got some way on, and passes the first pouch, a larger charge of powder, finer in grain, is ignited, and adds to the impetus of the moving shot; the same occurs at the second, third, and fourth pouches, each new supply of powder-gases adding to the speed of the projectile, which is said to leave the muzzle with a velocity of about 3500 feet per second, and to possess power of penetrating iron plates far beyond any Whitworth or Armstrong gun. Such a gun would doubtless give comparatively little strain upon the breech, but the powder-gases would have a very unusual amount of tension at the muzzle, and the amount of *kick* may be expected to be correspondingly large.

That the air has considerable effect in producing recoil appears evident from the fact that recoil takes place when there is no projectile, the gun being fired with blank cartridge.

Few persons appear to take the atmosphere into consideration in connection with recoil, yet air is a factor which ought not to be overlooked. It has already been shown, in page 65, that when bullets are passing through the open air, they encounter a resistance far beyond their own weight; and, with air inclosed in the gun-barrel, so that it cannot be pushed aside, but must be expelled from the muzzle, it may not unnaturally be supposed that the resistance it opposes to the passage of the bullet must greatly exceed that which it offers when it is free to move aside. If we attempt to thrust any close-fitting object rapidly through a long tube, the effect is very different from that of thrusting through unconfined air. We see, by the table just referred to, that, owing to the difference in shape, elongated bullets suffer much less obstruction from atmospheric resistance than is undergone by spherical balls; but when they are in the barrel, there appears to be no reason why they should have any such advantage—the amount of pressure would doubtless depend upon the area of the bore and the velocity of the bullet.

What is the extent of such resistance in the barrel under ordinary circumstances does not appear to be satisfactorily ascertained. The amount of atmospheric resistance to the bullet after it has left the gun has been worked out with great accuracy; but this is a very different matter from the action of the air in the barrel. In a paper by Professor G. Forbes, printed in the "Transactions of the Royal Society of Edinburgh" for 1879, it is calculated that, when a gun-barrel is choked by snow, dirt, or other obstructing matter, the pressure that would be set up by the advancing charge would be equal to about 7 tons per square inch, supposing the charge to have a velocity of 1000 feet a second, or about the velocity of sound, and the obstructing plug to have a density equal to that of water. It may be questionable, however, whether we should be justified in assuming that the charge would, under such circumstances, reach the plug with its full velocity; for the air in the barrel would be gradually driven forward from the instant the shot began to move, and would become more and more condensed as the shot advanced; and although under ordinary conditions it may be true that the velocity of sound is a measure of the rate of transmission of motion through the atmosphere, yet it is not proved that, under the extraordinary conditions of extremely high pressures, that rate of motion in the air will not be exceeded. We have, for example, projectiles driven through the atmosphere with about double the velocity of sound; and as an unusual amount of motion must be imparted to the air under those circumstances, may we not imagine that an unusual velocity may be imparted under the extreme pressure produced by the advancing shot in the barrel? If so, some amount of pressure may be transmitted to the obstructing plug in advance of the arrival of the shot; if not, the accumulating resistance of the compressed air in the barrel must be a considerable source of retardation to the shot, even when no obstructing plug interferes with its exit. At all events, it is not correct to assume that obstructions in the barrel invariably cause bursting, for there are many facts to prove the contrary. Some instances are mentioned at page 398 of the previous volume. Experiments have also been carried out on behalf of the United States Government, and it was found that of a large number of army rifles purposely choked with sand, &c., only a very small percentage were burst.

The effect of air-resistance in a gun-barrel was turned to account some twenty years ago by Mr. G. P. Harding in the production of what was called a "non-recoil gun." It was certainly a curiosity in its way, but apparently not of much practical value. It was simply a tube open at both ends, the charge being put in the centre, with a wad behind it, and a second wad placed further towards the end of the barrel, so as to shut in air between the two in much the same manner as it would be in a gun plugged by snow. When the charge was fired, the shot was driven out at one end of the barrel, but the wads still remained in at the other; and a gentleman who witnessed some of the experiments informed me that he saw the gun balanced on some support, and when the charge was fired the barrel remained unmoved. Doubtless the force exerted in driving out the shot was exactly counterbalanced by the compression of the air and shifting of the nearest wad as the pressure of the gases increased, and by a re-expansion and thrusting back of the wad as the pressure diminished.

A somewhat analogous experiment, carried out some years before by Colonel Parlby, is narrated in a work which he edited.* He took a musket barrel, made a new vent in the centre, and fired the charge therefrom with the hinder part of the barrel empty, and he found the penetration very little diminished from what it was when the powder was placed close to the breech; but the cushion of compressed air had so great an effect in diminishing recoil, that a 7lb. weight sufficed to keep the barrel in position in the one case, though a 50lb. weight was required in the other. That the recoil was only lessened, and not altogether removed in this case, may probably be owing to the fact that here there was a fixed breech, whereas in Mr. Harding's experiment there were two movable points, and in the compression and re-expansion of the air the second wad might be shifted to some extent, as well as that which was nearest the charge.

It is not impossible that, one of these days, some of our ingenious mechanicians may discover a means of introducing a reservoir of air behind the powder-charge, where it would probably have the effect, not only of lessening the initial recoil, and thus preventing muzzle disturbance, but might also add to the safety of the gun by reducing the sudden strain, where quick-burning powders are made use of.

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* Col. Anderson on "The Mode of Manufacturing Gunpowder at Ishapore Mills." Edited by Lieut.-Col. Parlby. London: Weale. 1862.

### EFFECT OF DIFFERENT CHARGES ON RECOIL.

It is not easy to find any comparative information about the recoil of rifles; but experiments that have been carried out with respect to shot guns will be serviceable, as showing the difference in recoil with the same charges of powder and varying weights of shot.

These particulars were ascertained by means of the *Field* machine-rest and recoil-gauge, an illustrated description of which is given at page 46 of the first volume of this work. The recoil of the gun, when fired, is registered on the scale of the Salter's spring attached to the machine, and thus shows when there is a difference of recoil by the difference in the number of pounds registered on this scale. I may frankly say I do not consider that these scale-numbers really give any idea of the actual pounds of pressure produced by the recoil; but they certainly give a means of comparison, and show most distinctly that there are considerable differences of recoil produced by alternating the weight either of powder or shot in the same gun, and also of firing the same charge from different guns. One defect which I conceive to exist in this apparatus is, that, owing to the effect of the spring, it underrates, rather than otherwise, the increase of recoil from heavier charges, and so makes them appear comparatively less severe than they really are. If, instead of relying on the ordinary Salter scale attached to the machine, a special scale were devised of a similar character to that attached to the *Field* force-gauge, and based upon the effect produced by falling weights, my belief is that a better means of comparison would be established. In like manner as the force-gauge admits of an estimate being formed of the actual velocity with which shot strike the target (as I have endeavoured to demonstrate at p. 343, vol. i.), so would a similar gauge applied to the recoil machine enable the velocity of recoil of the gun to be ascertained, supposing the weight to be known, and thus the energy of recoil in foot-pounds could be calculated. A heavy gun and a light gun might, on being fired with the same charge, show the same amount of recoil in one fashion, in consequence of their having equal momentum; nevertheless, the light gun would give a sharper blow to the shoulder by reason of its moving back with greater rapidity. This could be estimated in foot-pounds, if the velocity of recoil were known, but at present it cannot be ascertained. These remarks, however, are rather apart from my present purpose, which is to explain that, although, in my opinion, the pounds recorded on the Salter scale cannot be considered as true pounds, yet the figures about to be quoted show differences which really exist, and which would probably be accentuated to a greater extent if we could get the veritable results in foot-pounds.

The figures given opposite are obtained from the report of a long series of experiments carried out by Mr. R. W. S. Griffith, which were summarised and commented on in pp. 346 to 364 of the previous volume of this work. These experiments were carried out with the same gun, with varying charges of shot and powder, the shot being of different sizes and the powder of two kinds, viz., black (Curtis and Harvey) and Schultze. The mean velocities in a 40 yards range were taken with a Boulengé chronograph, and the recoil by means of the *Field* machine-rest. The record of each shot was originally published in the pages of the *Field*, but it will suffice here to give an abstract from the averages, from which there was, as a rule, but little variation. Where the charge of powder is given in drams, it means that such was the weight of the black powder, and that there was an equivalent charge of Schultze, viz., equal in measure or half in weight.

EQUAL CHARGES OF POWDER (3DRS.)

| Size of Shot. | Charge of Shot. | MEAN VELOCITY. | | RECOIL. | |
|---|---|---|---|---|---|
| | | C. & H. | Schultze. | C. & H. | Schultze. |
| No. 2 | 1 oz. | 913 | 914 | 82 | 75 |
| „ | 1¼ „ | 891 | 896 | 89 | 82 |
| „ | 1½ „ | 845 | 847 | 90 | 83 |
| No. 3 | 1 oz. | 905 | 919 | 84 | 76 |
| „ | 1¼ „ | 880 | 894 | 90 | 83 |
| „ | 1½ „ | 843 | 841 | 94 | 87 |
| No. 4 | 1 oz. | 890 | 893 | 85 | 76 |
| „ | 1¼ „ | 870 | 864 | 89 | 84 |
| „ | 1½ „ | 832 | 837 | 94 | 87 |
| No. 5 | 1 oz. | 874 | 883 | 85 | 77 |
| „ | 1¼ „ | 849 | 843 | 94 | 85 |
| No. 6 | 1 oz. | 860 | 858 | 86 | 79 |
| „ | 1¼ „ | 849 | 841 | 94 | 86 |
| No. 7 | 1 oz. | 829 | 842 | 86 | 78 |
| No. 8 | 1 oz. | 816 | 823 | 86 | 79 |

The velocities are inserted as well as the recoil, in order to show that the former keep very close together with the two powders, whatever the change in the shot, so that the difference of recoil cannot be the result of the difference of velocity. If we are to accept the statements that are made, as to the recoil of the gun being proportionate to the weight and velocity of the shot, the recoil with the two powders ought to be as close together as the velocities are; yet we invariably find a considerable difference between the recoils, and the proportion keeps much the same throughout all the changes. We find, for example, with No. 2, that the recoil of black powder was 7 higher than Schultze when 1oz. of shot was used; with 1¼oz., both go up 7, and with 1½oz. both increase 3 more. With No. 3 and smaller sizes a similar process goes on. Each reduction in the size of shot (the weight being unaltered) produces a greater amount of recoil, owing, no doubt, to the increased friction arising from a larger number of pellets pressing against the barrel; but whenever the recoil increases with the black powder, it increases also with Schultze, and the difference between them remains just about the same.

When the charge of shot remains stationary, but the powder varies in quantity, then we have similar differences of recoil between the two powders, except that there are wider intervals between successive steps:

VARYING CHARGES OF POWDER WITH EQUAL WEIGHT OF SHOT (1 OZ.)

| Size of Shot. | Charge of Powder. | Mean Velocity. | | Recoil. | |
|---|---|---|---|---|---|
| | | C. & H. | Schultze. | C. & H. | Schultze. |
| No. 2 | 2½ drs. | 847 | 856 | 70 | 64 |
| " | 3 " | 913 | 914 | 82 | 75 |
| " | 3½ " | 988 | 985 | 90 | 83 |
| No. 3 | 2½ drs. | 818 | 810 | 73 | 65 |
| " | 3 " | 905 | 919 | 84 | 76 |
| " | 3½ " | 982 | 985 | 91 | 82 |
| No. 4 | 2½ drs. | 807 | 809 | 74 | 67 |
| " | 3 " | 890 | 893 | 85 | 76 |
| " | 3½ " | 965 | 963 | 92 | 84 |
| No. 5 | 2½ drs. | 816 | 817 | 75 | 67 |
| " | 3 " | 874 | 883 | 85 | 77 |
| " | 3½ " | 942 | 927 | 94 | 86 |
| No. 6 | 2½ drs. | 759 | 781 | 76 | 69 |
| " | 3 " | 860 | 858 | 86 | 79 |
| " | 3½ " | 900 | 905 | 95 | 87 |
| No. 7 | 2½ drs. | 761 | 766 | 76 | 69 |
| " | 3 " | 829 | 842 | 86 | 78 |
| " | 3½ " | 895 | 901 | 95 | 87 |
| No. 8 | 2½ drs. | 776 | 791 | 76 | 71 |
| " | 3 " | 816 | 823 | 86 | 79 |
| " | 3½ " | 828 | 831 | 96 | 88 |

The very great regularity in the gradations—the velocities keeping side by side with the two powders almost invariably, and the recoil always being from about 6 to 8 less with the Schultze, according the charge—makes it clear that the general belief of sportsmen in the lesser recoil of the nitro-compound has a better foundation than the conclusion which some adhere to, that you must have equal recoil if you have equal velocity and weight of projectile.

How, then, is the difference to be accounted for? My impression is that it is a natural result from the lower density of the powder. Schultze powder, in its unburnt state, is about half the weight of black powder; and when the powder is exploded, the products of combustion cannot be heavier than the material from which they were formed The gas from the Schultze powder may not be very different in weight from that of the black powder, but the nitro-compounds have scarcely any solid residue, whereas the black powder has nearly two-thirds of solid residue when it is cooled, although when first fired it is in a kind of liquid condition, the solid particles being intimately mixed up with the true gas.

When one body pushes against another, the momentum imparted depends upon the weight and velocity of the moving body as compared with the weight of that which is moved; and this applies, not only to solids, but to fluids also. The effect of atmospheric pressure is dependent upon the weight of the air as well as its velocity; and the effect of powder gases upon the projectile is, in like manner, dependent upon their weight and velocity. What is wanting in weight in the gases of the nitro-compounds must be made up for by the velocity of their expansion.

If the action of the two powders were similar throughout, it might be assumed that the velocity of Schultze gases at all points of the bore would be double those of black powder; but it is not likely that such would be the case.

It is more probable that the velocity of both is more nearly equal when the shot leaves the muzzle, and that that portion of the recoil which occurs after the expulsion of the shot would depend for its effect upon the weight of the gases in the barrel as well as the rapidity with which they rush into contact with the atmosphere; and as the black powder gases (or, rather, the mixture of gas and solid particles) would be doubly as heavy as the Schultze gases, the action of the former on the atmosphere, and their reaction on the gun, would necessarily be greater than those of the latter.

There is, too, another point for consideration. If the same amount of momentum be imparted by two bodies, one of which is half the weight of the other, but moving with double the velocity, the "energy" or rending power of the two is not equal, for the energy is proportionate to the square of the velocity. If, then, a certain amount of momentum is imparted to 1⅛oz. of shot by 3drs. of black powder (a proportion of 1 powder to 6 lead), and equal momentum is imparted to 1⅛oz. of shot by 42grs. of Schultze (a proportion of 1 powder to 12 lead), there must be a higher velocity of expansion to afford the necessary impulse; and the strain on the barrel would be proportionate to the square of the velocity multiplied by the weight. If the velocity of expansion of the nitro-compound were exactly double that of black powder, and the latter double the weight of the former, we should have 2 × 2 × 1 as against 1 × 1 × 2; that is to say, the strain would be double with the nitro-compound. The effect becomes more marked when the rapidity of combustion is increased by the drying of the powder. If black powder be dried, it burns more rapidly, and greater energy is developed with the higher velocity of expansion; but the increase of velocity is kept within comparatively narrow bounds by a clog on the movement of the gases. The solid residue is nearly double the weight of the true gases, and the latter must impart motion to the former; consequently a check is put on the rapidity of expansion. With the nitro-compounds it is not so, for there is scarcely any solid residue. When there is a certain amount of moisture, that checks the rapidity to some extent; but, on the moisture being wholly abstracted, there is practically no check, and the mass explodes almost simultaneously, or, to use another expression, it "detonates;" for detonation is merely rapid explosion. In like manner as the difference between a push and a blow is a question of velocity, so is the difference between explosion and detonation. You cannot draw a line as to where the one begins and the other ends: detonation is quick explosion—the difference is merely one of time. The effect of this seems to be, that if means be taken to lessen the strain on the breech by reducing the velocity of explosion of the nitro-compounds, the time may be so lengthened that a kind of "hang-fire" is produced, owing to the want of weight in the propelling gases. If, on the other hand, a stronger cap be used to remedy the hang-fire, the result, on a minor scale, is the same as that produced by firing a disk of compressed guncotton by a large quantity of fulminate. Guncotton is rendered so inert by extreme compression, that it will burn almost as slowly as a piece of wood; but if compelled to burn more rapidly by a very powerful cap, it explodes with such violence that a small mass will suffice to shatter a fortress.

It appears to be clearly established that there are vast differences in the amount of force exhibited by these nitro-compounds under varying conditions. With change of circumstances, the same powder gives results very similar in the wideness of their divergence to what is shown to exist between the Rifle Large Grain and the Russian Prismatic Powders alluded to on page 85. Under certain conditions, the E. C. powder burns so slowly that complaints have been made of its hanging fire badly; and in such case the strain in the chamber of the gun would be very small, for, as with the Russian prismatic powder, the gas would be chiefly developed further on in the barrel. Under other conditions there may be produced a medium amount of force, which will suffice to give good shooting without undue strain upon the gun. But with still further change of circumstances, as such great restraint on expansion, increase of fulminate in the caps, or abstraction of moisture from the powder—any circumstance, indeed, which favours extreme rapidity of combustion—the violence of explosion also becomes extreme. I have in my possession a crusher gauge which has been used in a Martini-Henry rifle under the same conditions as that represented in Fig. 13, page 120, except that, instead of 85 grs. of black powder, the charge was 42 grs. of the large-grained yellow E. C. rifle powder. The result of the resistance of the Martini bullet was to so considerably develope the force in the E. C. powder, that the gauge was crushed down to a greater extent even than that shown in Fig. 14.

These remarks have, however, wandered away somewhat from the question of recoil; but I may state, in connection therewith, my belief that great rapidity of explosion in the powder, whether black or otherwise, is not only accompanied by a great amount of strain on the breech, but that there is more *initial* recoil imparted to the gun when the shot is set in motion, and less *kick* produced as the shot leaves the barrel; and, further, that the greater the strain on the breech—whether produced by a quick-burning powder, or a heavier bullet, or resistance of any other kind—the greater is the probability of increased "jump" or "muzzle disturbance."

## THE "JUMP."

The effect of the "jump" is nowadays a generally admitted fact, both with big guns and small arms; but if, as some persons contend, no motion is produced in the gun till barrel and shot part company, any subsequent movement of the one could scarcely affect the course of the other.

Professor Bashforth, in writing relative to a comparison of calculated and experimental ranges with cannon shot at high velocities, said: "It is probable that the experimental ranges will somewhat exceed the calculated ranges, because, when high charges are used, the 'jump' of the gun probably gives the initial direction of the shot an elevation sensibly greater than that for which the gun is laid." This would have the effect of causing the trajectory to appear to be flatter than it is in reality; for if, at the instant when the bullet leaves the rifle, the muzzle happens to be jerked slightly upwards, this additional elevation may cause a considerable difference in a long range, and the actual course of the bullet would be much higher than the apparent trajectory indicated by the sighting of the rifle.

Sir Joseph Whitworth, in his book on "Guns and Steel," has given the following interesting particulars of the increase in height of the projectile, and consequent extension of range, when shots were fired from one of his guns under different conditions:

> "A $2\frac{1}{2}$-pounder Whitworth mountain gun was first placed in a tube, with its axis coincident with that of the tube. On firing, the gun could only recoil in the exact line of the axis of the tube. The shot left the tube in a horizontal line, and its range was 100 yards.
>
> The same gun was then mounted on a field carriage of wood, and laid in a horizontal line. The elasticity of the carriage now came into play; the axis of the gun deflected upwards on recoiling, and the range was 204 yards. The projectile rose to a height of $10\frac{3}{4}$ inches above the horizontal line of fire.
>
> The gun was finally mounted on a field carriage of Whitworth metal. Here its axis is brought much nearer to the axle of the carriage, and the leverage which assists the deflection is correspondingly reduced; also the rigid steel yields less than the wood.
>
> The gun was laid, as before, in a horizontal line, and its axis

deflected upwards, but to a less extent. The range was 190 yards, but the shot rose above the line of fire to a height of only 8 inches instead of 10¾ inches. The trajectory, with a nearly equal range, was, therefore, much flatter; and the experiment is most instructive as demonstrating the influence of the carriage upon the trajectory of the gun."

Evidently there must have been motion in the gun sufficient to throw up the muzzle before the departure of the projectile; and the plate accompanying the text affords particulars which enable us to form an estimate of the angle of elevation produced in each case by the motion of the barrel. The drop below the axis of the barrel was 10 inches, the diameter of the shot was 1·9 in., and the weight 2½ lb.; and by means of the process already described, we are enabled to calculate approximately the velocity of the shot, and the amount of natural drop at the respective distances, and to see that the effects described are the natural consequence of the "jump."

The "jump" appears, however, to be by no means a definite quantity, and occasionally varies in the same rifle at different angles of elevation, besides differing at the same angle when there is an alteration in the charge. The latter result might be expected; but there seems to be no regularity of increase or diminution with increase or diminution of charge. In some artillery experiment carried out at Shoeburyness, and alluded to by Professor Bashforth, care was taken to measure the "jump" of the same gun at various angles of elevation from 5° up to 30°; but the figures show that there was not any uniformity of result corresponding with the increase of elevation; for in some instances the increase was large, and with others small, and in some cases the movement appears to have produced a negative instead of a positive result, and therefore to have thrown the shot lower instead of higher. In some cases, too, with the same gun, a small charge caused a greater "jump" than a larger one; and with a different elevation the opposite effect was produced. Possibly these differences of action may account for what appear to be occasional inequalities in the sighting of rifles, when the increasing height of the back sight does not follow the regularity of gradation which corresponds with the increase of range. The sighting of the rifle, not being a matter of calculation exclusively, has to stand the test of the target and to be regulated accordingly; and, if at one distance or one elevation, the "jump" happens to be greater than at another—if the bullet is high above the mark when the rifle has one angle of elevation, but strikes lower, or even under the mark, when the angle is different—alterations must be made to accommodate those variations, and there cannot, in such case, be the same regularity of gradation as if the "jump" had no existence.

With regard to differences of "jump" in rifles fired from the shoulder, it seems not at all improbable that something may be due to the difference of grasp and firmness of hold at different elevations, and also to difference of build in the shooter. One man is long in the neck and another short; and it is hardly to be expected that both will with equal ease align the sights for different distances. The long-necked man may look comfortably through the back-sight when raised to the height necessary for a long range; but, when it is lowered for a short range, he must either wrench his neck down awkwardly till it is in a line with the sight, or he must raise the butt of the stock to a higher part of the shoulder so as to bring the sight level with the eye. The short-necked man, on the contrary, may find the lower sights handy, but it being difficult to crane his neck up to the sights for long distances, he slips the stock a little lower down to the armpit. It is scarcely possible, under such circumstances, that either of these men will have an equally firm grip on his weapon at all elevations; and the "jump" may therefore take different proportions with variations in height of sight, and be different with the two men if they chanced to use the same rifle. With long-range rifles, fired from a prone position, any such cause does not, however, appear likely to hold good.

Mr. Metford's observations, both in his article (page 198) printed in the previous chapter, and in the chapter on sighting (page 225), are very pregnant, and throw light on various obscurities in the behaviour of rifles. It is well known that different guns will behave differently with the same charges of powder and shot, and that great changes may be produced in the performances of the same guns by varying the weight whether of powder or bullet. Some barrels, being made of more elastic metal than others, will expand more with equal charges of powder; while others differ considerably in their proportions of thickness at various parts of the barrel, as well as in length. Then there is the difference of construction between military and other rifles in the amount of woodwork, the bands that clasp the fore-end to the barrel, and other paraphernalia; and, on the other hand, where these are wanting, there are two barrels fixed side by side. All these things may produce differences of "flip," as Mr. Metford terms it, and more or less affect the aim in a way for which no general rule can provide, the only remedy being for the owner of the rifle to study its idiosyncracies and adapt himself thereto. Mr. Metford shows that one of his rifles is much more "tender" than another; and this would doubtless be acted on to a greater extent by the "waves of pressures" alluded to in page 81. He also shows the effect produced by a weight applied on one side of a barrel; and this, together with differences of "tenderness" in the material, may give a reason why the side-throw of some double-barrels is so much more difficult to regulate than that of others.

The effect of the "wave action" in a double-barrelled gun seemed well marked in one which recently came under my notice. The gun had been burst by E.C. powder, and the top rib had been driven completely out, in addition to a piece of the chamber. The rib, however, was not blown straight up and curled over, as sometimes happens, but seems to have been gradually removed by successive waves of motion proceeding down the barrel—the rib being bent into quite a serpentine form in its horizontal plane, as though action and re-action between the two barrels were going on throughout.

In artillery we have the "jump" looked upon as a regular thing, although it is anything but regular under change of conditions. In some cases it has been found that a certain increase of powder will give an increase of jump, and that a further increase in the charge will produce a "dip." A similar result may also happen from altering the weight of the projectile; and, on reflection, it does not seem very surprising that such should be the case, when read by the light of Mr. Metford's remarks. We have seen, by the table on page 85, at what different points of the barrel the maximum pressure will fall under different conditions in the powder charge; we have also seen, on page 120, how different is the amount of force exerted by the powder when it meets with greater resistance; and as there is likely to be a difference of expansion in the metal of the gun when the force acts upon a thicker or thinner part of the barrel, and also a difference of leverage according as the point of application is nearer or farther from the breech, we may thus account for many peculiarities of result with different guns. Possibly too, as we may not be able to provide a remedy for the idiosyncracies of particular weapons, we may arrive at the conclusion, that if we wish to obtain the best results, it will not be wise to take liberties with charges for which a rifle has been carefully regulated.

# CHAPTER VIII.

## SIGHTING.

THIS is so much a matter for the practical skill of the maker of the weapon, that little will be said upon it in this place. If there were nothing more to take into consideration than counteracting the drop of the bullet by the elevation of the muzzle of the gun, then the particulars given in previous chapters would indicate the lines upon which it would be necessary to go. Thus, with a drop of so many feet or inches, in a certain bullet and a certain range, an elevation of so many degrees or minutes of angle would give a rise equal to the extent of bullet-drop in such range. But this is only the mere threshold of the business. Two rifles made as a pair will not necessarily behave exactly alike, and they must be regulated according to their peculiarities. There has also to be provided for the difference of action of the same rifle according to the charge with which it is to be used. An elevation of so many minutes of angle may be required to compensate for the drop of a bullet in a given range; but it is found in practice that a less amount of elevation may suffice to enable the bullet to hit the mark. It is not that the drop is less and the trajectory really lower than was supposed, but that some movement in the barrel throws up the muzzle and gives it greater elevation than that produced by the sights alone. Under other conditions, too, if the barrel has a "dip," rather than a "jump" with a given charge, the sighting would have to be higher to counteract this effect. The build of the person who uses the weapon, and the means adopted by the gunmaker to fit it to the purchaser, may also in some cases affect the apparent though not the real amount of elevation.

If I am not mistaken, the course usually adopted by makers of match rifles nowadays is to sight for a very short range, such as a dozen yards, and, by studying the habits of the rifle with a given charge, so regulate it as to compensate for the idiosyncracies of the particular weapon within this short distance, and thus accommodate its jump. With the same charge of powder and lead, the jump may be assumed to be a constant quantity when once the quantity is known; and this being allowed for, a zero point is obtained, on which is based the elevation of angle required for the drop of the bullet at different ranges. The latter may be said to be a known quantity, although it will necessarily change with every variation in the charge; but the former is an unknown quantity, and the skill of the gunmaker is shown in the way he discovers and meets it. With any particular rifle, always used with the same charge, such as military weapons, the angles of elevation could be calculated; but with the infinite variety of sporting rifles, their differences of charges of powder and weight of bullets, it would be a hopeless task to attempt to give any useful tables.

Nevertheless, the tables of velocities and drop given at pages 143 to 153, may possibly be turned to account, as I will endeavour to show, by reference to the following interesting particulars supplied to me by a gentleman who carried out some experiments in order to ascertain the effect of altered charges on the drop of the bullet. He loaded with very great care three sets of ·450 cartridges containing charges of 105, 110, and 115 grains of powder and 280gr. bullet. He had the velocities of the bullets taken by chronograph, and found that 110grs. of powder gave about 40 ft.-sec. higher velocity than 105, while 115 gave about 30 ft. more than 110, the respective muzzle velocities being about 1820, 1860, and 1890 feet per second. He then tried at the target, at 100yds., cartridges from the three respective batches, and he found that those loaded with 115grs. placed the bullets about 3⅛in. higher than those of 110grs., and that the bullets from the 105gr. cartridges were 3⅞in. lower, making a difference of 7in. on the target for 10grs. difference of charge. It would be natural enough to assume that this 7in. difference in 100 yards was the result of about 70 ft.-sec. difference in muzzle velocity; but such is not the case. The mere reduction of velocity will scarcely account for 1-inch increase of drop, as will be seen by reference to the table given on page 146, where the drop of the 280grs. bullet is shown to be over 6in. with 1900 ft.-sec. and less than 7in. with 1800 ft.-sec. velocity in 100yds. We may therefore conclude that the rest of the difference is due to some other cause, and that that cause is most probably the variation of jump or flip produced by the alteration of the charge.

Assuming such to be the case, we may see that, with this rifle, there would be a difference of about 7′ of elevation required to compensate for the difference of effect produced by the alteration of 10grs. of powder in a range of 100 yards, whereas 1′ would suffice for the mere difference of drop produced by alteration of muzzle velocity. The remaining 6′ may be taken as a constant quantity applicable to all ranges, whereas the elevation for drop is a variable quantity increasing rapidly with length of range. At 200 yards there would be about 2′ increase of elevation required to compensate for the increased drop due to 100 ft.-sec. loss of velocity; and in 400 yards it would have grown so rapidly that about 12′ would be required to make up for the loss of speed; whereas the compensation for jump would continue as before.

We must not assume, then, that the mere variation in velocity of successive shots, fired with exactly the same charges of powder, will produce the same differences on the target as the alterations in velocity produced by increasing or diminishing the charge; but we may assume that if cartridges are so carelessly loaded by measure that one case contains several grains more powder than is put into another, the result may produce a very undesirable amount of irregularity in the shooting, not alone from the difference in speed, but from variation in jump. When, however, the powder is most accurately weighed, some degree of variation in successive shots cannot be prevented. The chronograph records of the rifles tried at Putney show that, in some instances, there was a variation of about 70 ft.-sec. in muzzle velocity in the course of the five successive shots. It is difficult to account for these variations, which no possible amount of care seems able wholly to eliminate; but the variations of velocity, in such cases appear to be as unimportant as the calculations would lead one to expect; for the same rifle which showed the 70 ft.-sec. difference of speed with the chronograph gave regular shooting at the target at Putney; and such is not surprising, if we take into consideration only the natural drop of the bullet. In the case of the experiments with the 280gr. bullets recently mentioned, we also find that the facts run on nearly parallel lines. The chronograph records from shot to shot vary, with the 105gr. cartridges, about 50 ft.-sec.; though with the other charges there was less variation. The difference between the highest of 105grs. and the lowest of 110grs. is, however, only about 20 ft.-sec. Accordingly, if speed alone had to be taken into consideration, the 105gr. cartridges ought, on the target, to be separated by more than double the space that would occur between the highest of the 105gr. batch and the lowest of 110grs. Such, however, does not appear to have been the case; and we may infer that when, with equal weights of powder and bullet, there are some differences in initial speed, but the other conditions remain unaltered, the effect produced is such as results merely from the difference of time of flight. But when the charge is altered, either in weight of bullet or of powder, or both, the conditions are no longer the same. The point of greatest strain in the barrel is changed, and complications are introduced by varying the nature of the jump or flip. The conclusions we may therefore draw from the observed facts are, that we should be chary of altering the charges of rifles which have been carefully regulated. Evenly-loaded cartridges will give fairly concordant results at moderate ranges, even if chronograph records do show a certain amount of variation in muzzle velocity; ill-loaded cartridges may, by the variation of charge, produce a greater amount of irregularity than mere difference of speed would suffice to account for; and if the sportsman deliberately alters his charge, and adopts one for which the rifle is not regulated, he must not blame the gunmaker if the results defeat his anticipations.

The following very interesting letter from Mr. Metford to Mr. Walsh has an important bearing on various matters connected with the sighting of rifles:

"*In re* of our Metford match rifle you speak of, and its sighting. There is a long and curiously interesting story attached to the sighting affair. You say your measurements "indicate a drop of 1½in. at 12yds."

When I began scientific rifle work—now, I am sorry to say, over thirty years since—I felt that the proper thing would be to rig up a telescope sight, and that it would also be a proper thing to put its optical axis (in which line the cross-wires lay) absolutely parallel with the axis of bore. This I did with all the caution and skill I was master of (I was at that time able to make a theodolite, bar the dividing and optical glass work). With my telescope set to zero (or parallel with bore axis) I went to shoot at 25yds., speed 1400ft., therefore drop of bullet at 25yds. a trifle over ½in. Telescope was 1in. above bore axis, therefore I expected the bullet to strike 1½in. under centre of spot (rifle not rested). Nothing of the sort happened; the bullet struck a considerable distance under. I at once thought I had made some stupid blunder, and reset the whole work again, but still the rifle did the same.

I then fired the rifle laid flat to right, then the bullet struck nearly as much to left, and rather under. Again I laid the rifle flat to left, and this reversed the strike, the bullet going to right and a little under. I then came to the conclusion that the barrel was curved, and that I had overlooked it; but I could not, on examination, see it was at all curved.

I then found this peculiarity attended all rifles, but with variation, and had nothing whatever to do with the bore *in re* its straightness.

The point is, What is the cause?

Bidder, about twenty years since (now dead), who had also detected with Whitworth's rifle the peculiarity, proposed to me that it was some effect of gravity; that the nose of the long bullet began to fall before the heel could, and so it took a dive; but my sideways shooting annihilated this, as he admitted. He had not tried this.

My friend William Froude solved it, and showed clearly that it was entirely due to the mass of the stock being unsymmetrical with the mass of the barrel; and that the first thing the barrel would do, on explosion, would be that the muzzle would flip down, the barrel bending in a curve (this flip down would be dependent for its amount and velocity on the masses, and length, and stiffness, and charge of powder, &c.); and that eventually the whole motion would reverse itself, and the whole gun kick up; but that the bullet would be gone before the barrel had returned to its level and above it, unless the barrel was very stiff and short.

This matter was, I believe, first publicly treated of by me in an article on trajectory I wrote at the desire of one of the American sporting papers in 1878, and which was afterwards, I think, much discussed in that paper, or, anyhow, one of the American sporting papers, by men who had not seen my article, but had themselves come across the fact as a new and curious thing. I did not enter into the discussion myself.

I find, too, that if one puts a mass (say 2lb.) on either side of a rifle, if (say) left side the barrel it will throw left, and *vice versâ*.

Rifles differ in amount of flip—*e.g.*, that original explanation of mine gave 14′ angle = at 12yds. to 1¾in. about; and gave for side (telescope on left) 5′ to left. One of my match rifles is only 9½′;

another equally stiff, apparently 22′. One of my rifles flips much the same amount whether I use quick or slow powder (initial speed being equal). Another rifle I know is, on the contrary, curiously tender, and so tender that I can actually tell which powder is being used.

Weights of powder and bullet affect it as well. You will see that there will be developed a lot of additions from the following cause: that the barrel, on the bullet passing muzzle, may either be progressing down, or at its lowest, or returning.

Only a fortnight since a friend "*announced*" a wonderful discovery of someone he knew; and, on inquiring, I found that the "someone" had just come across the flip as a brand new find, and the someone was going to stop it! Now the joke of it is, that it happens to be a convenient caper of the rifle, as it permits a much lower front sight for 100yds. ranges.

Look at a pistol which won't flip, on account of short stiff barrel, but kicks up straight off. What a bore is the high front sight.

Again, clearly a rifle with a very heavy muzzle, and other things being equal, behaves differently to a light muzzle in this matter. I inclose what I said in the American paper about it. [This extract forms part of Mr. Metford's article reprinted in the previous chapter, and the passage in question occurs on page 198.]

You will see now that the rifles are set, not to the constructive zero, but to the tangent of the barrel as curved by the joint, and at muzzle, or say parallel to the first foot of the bullet's flight.

My instruction to Gibbs for zero is, to put up a spot ⊙ at 12yds., and to so adjust the shoot that the bullet, when the slide is at zero, should cut a line below the spot $1\frac{1}{4}$in., the $1\frac{1}{4}$in. consisting of (1) the height of the eye-line above the bore-line = $1\frac{1}{8}$in., and (2) $\frac{1}{8}$in. for the drop of bullet by gravity at the 12yds.

This method of setting zero enables one to entirely escape all bothers *in re* flip.

Still, as many rifles alter their flip, if the powder be changed in either amount or velocity of explosion, and if the weight of bullet be altered, it is necessary to ascertain again the zero on making such alterations, all or any of them, otherwise a man may be led into considerable error in statements as to his 1000yds. angles (say).

I have known a rifle shoot precisely identical angles apparently at 1000yds. with two entirely different charges, but, when zeroed, a difference of 6ft. or 7ft. would be found existing. I have known one man prove that an addition of 60grs. to his bullet did not alter the drop at 1000yds. at all, and so mislead another man, who would get desperate ricochets.

The fact is, even a match barrel, stiff as it looks, is really a very limp affair, for one can grossly chuck it out of line with one's fingers and thumbs. I trust all this rigmarole will be sufficiently clear to explain the zero anomaly.

The behaviour of a military rifle with its fore-end on, and then off, will give a very funny exposition of flip.

I hear there is some rumpus up about the non-cleaning rifles, as if it was any new matter. Why, it was my easy shallow rifle, first introduced by myself in the Whitworth times, which finished up all the rifles which had deep grooves, and drove Whitworth and his followers out of the field, simply because my rifles would not catch the dirt like the heavy Whitworth, Rigby, and Ingram and Henry rifles did.

Again, my military breechloader, which first appeared at Wimbledon in 1871, and which has only missed the Duke of Cambridge's 1000yds. prize (the great "any military" breechloader) twice since, has always shot dirty and with no lubrication; my friends have always said it shot better dirty than clean.

It is true I lost the Duke's in 1881, but the rifle which took it required a lot of tallow in the cartridge (Webley-Wyley's), which is not a military cartridge, as fat will run in hot climates, and is not, therefore, allowed in military work.

I began my breechloading experiments in 1870 (I think it was; I can't look at my experimental books now) by laying down the law that no lubrication should be allowed, as unmilitary; and last year my rifles at Wimbledon, I may say, swept the field; at least, my military rifle took *every first*, "any military" rifle prize, and about 75 per cent. of the rest. And my match rifle permitted no English, Scottish, or Irish rifles to take any first "any rifle" prize whatever. My only competitor was Sharp, and he did not hurt me much.

Again, ten out of the twelve rifles in the American and British match were mine, and the two not mine stood well down the lower half. All my rifles worked without lubrication, and in the great heat too. The other two rifles, I think, had lubrication. Considering all this, it appears to me that for any one to have promulgated the idea that for a rifle to run clean enough and shoot well was a new and great discovery at this late date is laughable.

The very last shoot I had but one (for Sir H. Halford) at 1000yds., no cleaning, was all bullets *but one* in a vertical $\begin{smallmatrix}\wedge\\ \\ \vee\end{smallmatrix}$ of 18in. and the whole in 2ft. 4in. Fifteen shots, no lubrication. It looks like a mean vertical deviation of about 5in. to 6in. for the lot; but I did not work it out (see diagram, Fig. 19.).

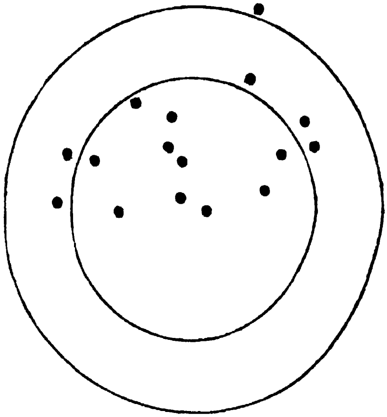


FIG. 19.

You see, therefore, that I feel somewhat confounded at all this trumpet blowing, when the fact of my breechloader rifle shooting without cleaning for all these years with the greatest success, and with no lubrication, has been staring every one interested in this special work in the face.

I must now "trip and trail" up my unfortunate scrawling, and make it more possible to read, and so remain, yours faithfully,

W. E. METFORD.

P.S.—I suppose soon the shooting people will discover my hardened cylindrical bullet and announce it to the world as a new and excellent affair, not knowing that I introduced it in 1856, and that all our long-range rifle makers have used it ever

# CHAPTER IX.

## INFLUENCE OF THE WIND.

THE drift of the bullet with the wind is more a matter for practical experience than theoretical explanation. It has already been briefly stated, under the head of Atmospheric Resistance (page 73), that the drop of the shot is increased or diminished by the retardation or enhancement of speed when the wind blows from front or rear; but the extent to which it will affect a bullet in a given range must depend upon the weight and shape of the projectile as well as length of range and force of wind; and here the sportsman's own judgment, based on the knowledge of his weapon and bullet, must be the chief guide. And if this be the case with head and rear winds, still more must it hold good of cross-winds blowing at different angles. The effect of these on light Express bullets is much greater than on heavy elongated projectiles; and this will scarcely seem surprising when we consider that many of these bullets are more or less hollow in front. Being thus light forward, a side wind would have most influence on that end of the projectile, and the effect would be much the same as that of the rudder of a ship being so applied as to turn the head of the vessel to leeward—it would run down-wind to a considerable extent. On the other hand, if a bullet were hollowed in the rear, so that the centre of gravity were thrown in the front, the effect would be the reverse of the above—it would be as if the helm turned the vessel's head to windward; it would "eat into the wind," and the drift

small. Even with short Express

, there would be a tendency

to drift more than the long projectiles used with military and match rifles, because the head forms a much larger proportion of the whole mass. If the bullet were a perfect cylinder, the side pressure would be equal throughout; but the head presents to a side-wind a larger area, in comparison with weight of metal, than the cylindrical portion of the bullet; consequently it gives way more to the side-pressure, and drifts down-wind more than the mere force of the breeze would otherwise account for.

For military and match-rifle shooting there are numerous handbooks which give instructions as to the use of the wind-gauge, and allowances to be made for the Martini and other bullets according to the "state of the clock," or position of the wind, supposing that the marksman uses his watch-face as a handy substitute for a compass. This practice is alluded to in the following observations from letters written by Sir Henry Halford and quoted by Lieut. Zalinski in the article from which an extract has already been made (page 180):

"I do not know the real angles of the rifles you used to make your calculations with, but you will see in Mr. Metford's paper, the angles of the rifles from which most of my experiments have been made. I have also shot much with Sharp's and Remington's rifles with practically the same speed and weight of projectile, and they agree with Mr. Metford's rifles in wind deflections, as they naturally should from having the same speed, form, and weight of projectile. I have also used a 380gr. bullet at very high speed, giving an angle of 2° 2′ at 1000 yards, but from its lightness it is deflected as 10 is to 7 compared with a 550gr. bullet. [The ratio of deflections in this instance is in the inverse ratio of the weights.—E. L. Z.]

The general angle of the rifles I have used with match charges of 90grs. Curtis & Harvey No. 6 is 2° 15′, with the thermometer at 50° Fahrenheit. On my card you will see that a wind which would give 30′ deflection if square across, would require a rise of 5′ if from 12 o'clock. A 430gr. bullet requires 8′ rise for head wind, a 570gr. only requires 3′! Mass tells.

I may mention that all our sighting is in degrees and minutes of angle, and the wind gauges are also cut to minutes. We find it the easiest way of working. The rifles are all shot for zero at 12 yards before the scale is cut, so that I can take up any of Mr. Metford's rifles and expect to get the sighting first shot, as well as with a rifle with which I am well acquainted.

I find the effect of temperature on angle is that, say from freezing point to 90° Fahrenheit, every $4\frac{1}{2}$° of rise of temperature require a lowering of 1′ of angle. There is, too, some queer difference in winter and summer of angle, not entirely due to temperature, and I find winter angles raised more than summer. For instance, I have shot in winter with the thermometer at 48° and the same in summer, and in winter I require 2′ or 3′ higher angle, and this not due to wind. I cannot yet give a reason for this, but hope some day to find out. They are not due to difference of barometer, for I noted that point.

I see you have taken great pains with your tables. Ours are based on 20 years' hard shooting, with the wind taken with a Lind's gauge and with a spinning gauge; also a pocket spring gauge with a chronometer spring set to grains weight on centre of disk. I never now, or hardly ever, use a wind gauge, as I trust to feeling. I also, like you, make use of the smoke from the rifle. . . . .

It is almost impossible to lay down a law or make a table that will suit more than one projectile for effect of wind on trajectory. The card I sent you will suit bullets from 540grs. to 570grs. in weight. A 480gr. military bullet will require the head column to be nearly doubled when shot from the same barrel. Again, the old bluff-nosed bullet required more elevation for head winds, so I think one must be satisfied with getting practical results, for I don't see how one can lay down a law. And as to side wind, I think I told you than a 380gr. bullet with an angle of 2° at 1000 yards, requires as 10 : 7 over match bullet 560grs., with angle of 2° 10′.

American riflemen are very frightened at changes of light. For my own part I cannot see that they make a difference, provided one is careful not to take a fuller or finer sight, and with a match rifle I never heed changes of light. I have set carefully a theodolite and watched it for days, and could not detect any alterations of the object due to refraction. . . . .

Graduations. 5′ = 5in. roughly for every 100 yards, is very easy to see and easy to calculate. I have these spaces on my military rifle, and one can set sights very accurately with it.

Some years since Mr. Metford and I got up some half-inch calibre rifles weighing 15lb. for 2000 yards, with telescope sights and did very good work with them. I could reckon on hitting 12ft. by 12ft., but it was felt that two sorts of small arms ammunition would not be practical; so the matter was dropped. And, moreover, it would have been difficult to get a soldier to stand the recoil of 150grs. of quick powder and 700grs. of lead. We used percussion shell, and very nice they were."

With regard to "minutes of angle," it may perhaps be worth mention that one minute (1′) is equal to about an inch in 100 yards; and it would apply equally if it were an angle of elevation to compensate for the drop of the bullet, or an angle of side, to compensate for its drift. An angle of one degree (1°) is very nearly equal to a slope of 1 in 60, or 1 inch in 5 feet, or half an inch in a 30in. barrel. As there are 60 minutes in a degree, a minute of angle is equal to a slope of about 1 in 3600; and there are 3600 inches in 100 yards. Accordingly, an elevation of 1′ is equal to a rise of about 1 inch for every 100 yards; an elevation of 1° equals a rise of about 5 feet per 100 yards; and so on. The Government angle for the Martini-Henry at 1000 yards is near about 3½°. This angle would consequently be equal to about 17½ feet in 100 yards, and to about 175 feet in 1000 yards. The drop of the Martini, with 1350 ft.-sec. muzzle velocity, is shown at page 153 to be 186 feet; so that, supposing the angle of elevation to be just as stated, there would be about a dozen feet to account for. The minute of angle is, however, a fraction more than an inch in 100 yards; besides which there is the "jump." Air-resistance, too, would tend to check descent in the bullet, as its drop velocity would exceed 100 ft.-sec. in 1000 yards, and resistance be proportionate to the square of velocity; but with sporting rifles the effect would be practically *nil*, the drop velocity of Express bullets in 150 yards being only about 10 ft.-sec.

# CHAPTER X.

## RETENTION OF ENERGY AND PENETRATION.

THE muzzle velocity of the bullet is not the only thing that concerns the sportsman in choosing his rifle and projectile. This speed is but a means to the end he has in view. He wants to kill his game at a greater or less distance, and not at the muzzle of the gun. According to the nature of the bullet, so will the velocity dwindle away; and one bullet which has the greatest initial speed may, by reason of its lightness, have lost that advantage by the time it has gone a hundred yards, and it will consequently not only strike with less force than another which had a smaller nominal power at first, but, by reason of the loss of speed, it will have a higher trajectory at all longer ranges.

Some tables have already been given showing the diminution of velocity and the amount of drop of eight typical bullets of ·450 bore at different ranges; and these tables also apply to forty-eight other bullets of different calibre, whose weights are stated on page 142. But although certain particulars have been given relative to these fifty-six bullets, nothing has been said to indicate what is the amount of "energy" or working power that they respectively possess; and the energy is, in some respects, a better gauge of their merits than the muzzle velocity, which merely tells the speed with which the shot leaves the barrel.

The energy of a moving body is ascertained from its weight and its rate of motion, and the unit of work is, in this country, usually denominated a "foot-pound." The most simple example of this unit of work is when a pound weight is lifted 1 foot. An amount of force equal to 1 ft.-lb. would be generated by dropping 1lb. a space of 1 foot; and 1 ft.-lb. of energy would be required to project the same weight the same distance upwards. The number of foot-pounds is estimated, in one way, by multiplying the weight of the body by the number of feet of fall, so that 1lb. dropped 100ft., and 20lb. dropped 5ft., or any other multiples that produce the same result, will give an equal number of foot-pounds; and, in another way, it is estimated by multiplying the weight by the square of the velocity and dividing the product by 64.

The figures on page 51 show that a weight falling for a certain time acquires a velocity equal to 32 feet per second; that the space passed through in a given time is equal to the mean velocity during that time; and that the square of the time, multiplied by the half of 32 ft.-sec. (16) gives the total drop. On the other hand, if the final velocity be squared, and the product divided by twice 32 ft.-sec. (64), we also get the total drop. Applying these facts to the ascertainment of foot-pounds, we find that 1lb. weight acquires 8 ft.-sec. velocity in dropping 1 foot, and, conversely, that if 1lb. be projected upwards with 8 ft.-sec. velocity, its rise would equal 8 × 8 (64) divided by 2 × 32 (64), so that the height would be 1 foot and the result 1 ft.-lb. If the velocity were 800 ft.-sec. the result would be 800 × 800 (640,000) divided by 64, which would give 10,000 as the number of foot-pounds of energy; and, were it not for the resistance of the atmosphere, a 1lb. shot projected upwards with 800 ft.-sec. velocity would rise 10,000 feet before its energy was exhausted in raising its own mass against the force of gravity. When fired horizontally, the shot would have the same original amount of energy as when fired vertically; and such portion as is not expended in overcoming atmospheric resistance would be available against any object with which it comes into contact. Accordingly, if we take the velocity of any of the bullets mentioned in previous tables, square that velocity, multiply by the number of grains the bullet weighs, and divide by 64 (twice 32 ft.-sec.) and by 7000 (the number of grains in a pound), we get the number of foot-pounds of energy there is in the bullet at the particular point.

The energy of all the ·450 bullets mentioned in tables from pp. 143 to 153 are thus calculated in the table on p. 237; and as it would be inconvenient to refer to and fro to ascertain the velocities of the respective bullets, these also are collected together for facility of comparison. The amount of energy applies only to the eight bullets of ·450 calibre, because the weight of the other bullets alter more or less according to the size of the bore; but the velocities apply to the bullets of all calibres. If the energy of the larger or smaller bullets is required, it may be ascertained by the process just described; but a less troublesome method is to take from the table of energy the number of foot-pounds given for the ·450 bullet, and multiply this number by such one of the following factors as applies to the calibre of the bullet whose energy is to be ascertained:

| Bore. | Multiple. | Bore. | Multiple. |
|---|---|---|---|
| ·360 | ·64 | ·420 | ·87 |
| ·380 | ·71 | ·500 | 1·23 |
| ·400 | ·79 | ·577 | 1·64 |

Thus, if we take the energy of the ·450 bore bullet of 360grs. at 100 yards, with 1700 ft.-sec. muzzle velocity (1650 ft.-lb.), multiply by 79 and cut off the last two figures or decimals, we get 1094 ft.-lb. as the energy of the ·400 bore bullet of the same type, which the table on page 142 shows to weigh 284grs. In some cases an error of a pound or so may arise from the decimals in the multiple not being carried further, but this slight difference is immaterial.

REMAINING VELOCITIES OF THE TYPICAL BULLETS AT DIFFERENT RANGES.

| Weight of Bullet and Muzzle Velocity | YARDS DISTANCE FROM MUZZLE OF RIFLE. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 100 | 150 | 200 | 250 | 300 | 30 | 400 | 450 | 500 |
| Grs. | Ft.-sec. | Ft.-sec. | Ft.-sec. | Ft.-sec. | Ft.-sec. | Ft.-sec. | Ft.-sec. | Ft.-sec. | Ft.-sec. | Ft.-sec. |
| **260** | | | | | | | | | | |
| 2000 | 1787 | 1592 | 1413 | 1257 | 1130 | 1036 | 974 | 919 | 870 | 826 |
| 1900 | 1696 | 1508 | 1338 | 1195 | 1081 | 1006 | 948 | 896 | 849 | 807 |
| 1800 | 1604 | 1423 | 1266 | 1137 | 1040 | 977 | 922 | 873 | 828 | 788 |
| **280** | | | | | | | | | | |
| 1900 | 1710 | 1534 | 1372 | 1233 | 1118 | 1034 | 976 | 925 | 878 | 837 |
| 1800 | 1617 | 1448 | 1297 | 1171 | 1069 | 1003 | 949 | 900 | 856 | 816 |
| **300** | | | | | | | | | | |
| 1900 | 1722 | 1556 | 1403 | 1267 | 1154 | 1062 | 1002 | 951 | 906 | 864 |
| 1800 | 1629 | 1470 | 1325 | 1202 | 1100 | 1027 | 973 | 926 | 882 | 843 |
| 1700 | 1536 | 1384 | 1252 | 1141 | 1053 | 995 | 945 | 900 | 859 | 822 |
| **330** | | | | | | | | | | |
| 1800 | 1645 | 1498 | 1363 | 1244 | 1144 | 1062 | 1007 | 960 | 917 | 878 |
| 1700 | 1550 | 1411 | 1286 | 1179 | 1089 | 1025 | 977 | 933 | 892 | 855 |
| **360** | | | | | | | | | | |
| 1800 | 1657 | 1522 | 1395 | 1282 | 1184 | 1100 | 1036 | 991 | 949 | 911 |
| 1700 | 1563 | 1433 | 1315 | 1212 | 1124 | 1052 | 1004 | 961 | 922 | 886 |
| 1600 | 1468 | 1347 | 1240 | 1148 | 1070 | 1017 | 973 | 933 | 896 | 862 |
| **400** | | | | | | | | | | |
| 1600 | 1481 | 1370 | 1270 | 1183 | 1107 | 1046 | 1003 | 965 | 929 | 896 |
| 1500 | 1387 | 1286 | 1196 | 1118 | 1054 | 1010 | 971 | 935 | 896 | 870 |
| **440** | | | | | | | | | | |
| 1500 | 1397 | 1303 | 1219 | 1145 | 1081 | 1033 | 995 | 961 | 928 | 898 |
| 1400 | 1306 | 1222 | 1147 | 1083 | 1034 | 996 | 962 | 929 | 899 | 870 |
| **480** | | | | | | | | | | |
| 1350 | 1268 | 1195 | 1115 | 1072 | 1038 | 996 | 964 | 934 | 906 | 879 |

On comparing these tables, it will be observed that the higher the velocity and the lighter the bullet, the greater is the loss of speed; and that a 260gr. bullet which starts with 2000 ft.-sec. velocity loses more than 400ft. of that velocity in the first 100 yards. At the end of that distance, a bullet 20grs. heavier, and starting with 100ft. less speed, already equals it as regards energy, and in longer ranges surpasses it in velocity. The same thing goes on with each increase of weight; 20 or 30grs. addition to the bullet soon compensating for 100ft. less muzzle velocity.

ENERGY OF ·450 TYPICAL BULLETS AT DIFFERENT RANGES.

| Weight of Bullet and Muzzle Velocity | YARDS DISTANCE FROM MUZZLE OF RIFLE. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
| Grs. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. | Ft.-lb. |
| **260** | | | | | | | | | | | |
| 2000 | 2321 | 1853 | 1471 | 1159 | 917 | 741 | 623 | 551 | 490 | 439 | 396 |
| 1900 | 2095 | 1669 | 1320 | 1039 | 829 | 678 | 587 | 522 | 466 | 418 | 378 |
| 1800 | 1880 | 1493 | 1175 | 930 | 750 | 628 | 554 | 494 | 442 | 398 | 362 |
| **280** | | | | | | | | | | | |
| 1900 | 2204 | 1828 | 1471 | 1176 | 950 | 781 | 668 | 595 | 535 | 482 | 438 |
| 1800 | 2025 | 1634 | 1310 | 1051 | 857 | 714 | 629 | 564 | 506 | 458 | 416 |
| **300** | | | | | | | | | | | |
| 1900 | 2417 | 1986 | 1621 | 1318 | 1075 | 892 | 755 | 672 | 606 | 550 | 500 |
| 1800 | 2170 | 1777 | 1447 | 1176 | 967 | 810 | 706 | 634 | 575 | 521 | 476 |
| 1700 | 1935 | 1580 | 1283 | 1050 | 872 | 743 | 663 | 598 | 543 | 494 | 452 |
| **330** | | | | | | | | | | | |
| 1800 | 2387 | 1993 | 1653 | 1369 | 1140 | 964 | 831 | 747 | 679 | 619 | 568 |
| 1700 | 2152 | 1770 | 1466 | 1218 | 1024 | 873 | 774 | 703 | 641 | 586 | 539 |
| **360** | | | | | | | | | | | |
| 1800 | 2603 | 2206 | 1862 | 1564 | 1321 | 1127 | 972 | 862 | 789 | 724 | 667 |
| 1700 | 2322 | 1963 | 1650 | 1390 | 1180 | 1015 | 889 | 810 | 742 | 683 | 630 |
| 1600 | 2057 | 1732 | 1458 | 1236 | 1059 | 920 | 831 | 761 | 699 | 645 | 597 |
| **400** | | | | | | | | | | | |
| 1600 | 2286 | 1959 | 1676 | 1440 | 1250 | 1096 | 977 | 898 | 831 | 771 | 717 |
| 1500 | 2009 | 1718 | 1477 | 1277 | 1116 | 991 | 911 | 842 | 781 | 717 | 676 |
| **440** | | | | | | | | | | | |
| 1500 | 2210 | 1917 | 1668 | 1459 | 1288 | 1148 | 1048 | 972 | 907 | 846 | 792 |
| 1400 | 1925 | 1675 | 1467 | 1292 | 1152 | 1050 | 974 | 909 | 848 | 794 | 743 |
| **480** | | | | | | | | | | | |
| 1350 | 1953 | 1723 | 1529 | 1332 | 1240 | 1154 | 1063 | 996 | 935 | 880 | 828 |

It may be said, with regard to the comparative effects of speed and weight, that higher muzzle velocity gives a lower trajectory. So it does, for short ranges; and it is entirely a matter for the sportsman's consideration whether the flatness of trajectory is sufficient compensation for the loss of power within the range for which he chiefly intends to use his rifle. By comparing the three tables of trajectories on pages 145, 149, and 151, it will be seen that, in a range of 150 yards, the trajectory of the 260gr. bullet is about two-tenths of an inch lower than the 300gr. bullet with

100ft. less initial speed, and half an inch lower than the 360gr. bullet with 200ft. less velocity; at 200 yards the trajectories of the three bullets are about equalised; and, after 300 yards, the lightest bullet, despite its high muzzle velocity, has not so flat a trajectory as either of the other two, while in striking force it is much inferior.

Upon its striking force of course depends the power of penetration of the bullet. And here another question for the sportsman's consideration is the nature of the penetration he wishes to obtain. A long and slow bullet will drill through a thin-skinned animal without expending its force, and, by giving little shock to the system, will leave the beast with nearly all its vigour to escape pursuit, or perpetrate mischief for the time being, although it may have received a mortal wound and eventually die a lingering death. On the other hand, a light hollow-fronted bullet may be smashed up on a tough hide, without ever penetrating at all.

So much depends upon the nature of the projectile and of the substance against which it is impelled, that it is difficult to give any general idea as to the penetration of bullets. We can here only proceed on the assumption that the target at which they are fired admits of penetration, and gives equality of resistance, and that the bullet does not change its form on impact. In such case, the penetration of bullets of the same calibre and the same shape would be proportionate to the square of their velocity multiplied by their weight.

Bullets having the same energy, but differing in calibre, would not, however, have the same power of penetration, for they would be met with an amount of resistance proportionate to the square of their diameter. Hence, if two bullets, of ·500 and ·400 bore respectively, and of the same weight, struck with the same velocity, their energy would be equal, but the resistance to the larger bullet would be as 25, and to the smaller as 16, so that the former would only penetrate about two-thirds as far as the latter. With some kinds of game the extra penetration would be an advantage; with others it would be better to have less penetration and greater local shock. Accordingly, in the choice of projectiles, the means must be adapted to the end.

In the case of the bullets to which the foregoing table of energy is applicable, all that are of the same type would have equal power of penetration, because their weight increases or diminishes at the same rate as the area of resistance. But between bullets of different types this would not hold good. Those of the same calibre would increase in penetration with increase of weight, supposing their velocity to be equal; but where the area of the bore increases more rapidly than the increase of weight, the penetration would diminish; and *vice versâ*. Thus, with 100 ft.-sec. difference in initial speed, the energy of the 260gr. bullet and of the 280gr. bullet of ·450-bore are equal at 100 yards (see p. 237), and we may therefore expect the penetration to be equal; but if a ·400 or other bullet had the same velocity as a ·450 bullet of the same weight, the energy would be equal, but the penetration would be greatest with the smallest bore. The amount of difference may be estimated by means of the multiples on page 235. Supposing, for example, it were known that a bullet of ·450 calibre, with a given energy, penetrated twenty boards of a particular kind, the proportionate penetration of a ·500-bore bullet, with the same amount of energy, would be 20 ÷ 1·23, or about sixteen boards. The proportionate penetration of a ·400-bore, with the same energy, would be 20 ÷ ·79, or twenty-five boards. If we know the penetration of a ·500 bore, and want to get that of a ·400 of equal energy, we multiply by 1·23, which brings the ·500 to the ·450 standard, and then divide by ·79, which gives the ·400 equivalent.

In Messrs. Holland's trial in 1879, the penetration of

1in. yellow pine boards by ·577-bore solid Express bullets, hardened by 1 part of tin to 9 of lead, was, in round numbers, at the rate of one board to about every 120 ft.-lb. of energy. With a ·450 bullet, owing to the smaller area of resistance, we might estimate the proportion as 120 ÷ 1·64, or about 73 ft.-lb. per board; if it were a ·400 bullet, the corresponding proportion would be 73 × ·79, or one board for about 58 ft.-lb. of energy. But in all practical experiments, the actual penetration would necessarily depend upon the relative softness in the wood and its freedom from knots.

## Concluding Remarks.

The main purpose of the writer of the previous chapters has been, while treating of theoretical matters, to endeavour to render them of some little practical value to those for whom the book is chiefly intended; and recourse has therefore been had to such available facts as would best illustrate the questions under discussion. If a more ample supply of facts about sporting rifles had been forthcoming, the result might have been more satisfactory; and any further records of comparative trials with different weights of powder and lead will be gladly accepted, as such records are valuable in forming a basis for more definite conclusions.

These notes have been expanded far beyond the writer's original intention, and yet he is sensible that various points have been passed over with little or no notice. Some, no doubt, are topics of more interest to the artillerist than to the sportsman, whose projectiles are in motion for very brief periods of time, and have comparatively small amounts of rise and fall. But the theme is almost boundless in its scope; and the anticipation expressed in the first of these chapters is fully verified on arriving at the last, viz., that the subject would not be exhausted here. T.

# BOOK V.

# THE MECHANICAL CONSTRUCTION OF THE SPORTING RIFLE AND ITS AMMUNITION.

## CHAPTER I.

## GENERAL PRINCIPLES OF CONSTRUCTION.

The main difference between a shot gun and a rifle lies in the barrels, those of the latter being so much the heavier and stronger. The breech action and stock of a rifle also require greater strength than the similar parts of a shot gun, but to a less marked extent. The rifle also has almost invariably the pistol hand grip instead of the straight hand of the shot gun. Most of the breech actions described in Volume I. can be applied to double rifles for sporting purposes, as in fact many are, but single rifles require somewhat different treatment, as we shall hereafter see. I propose, therefore, to confine myself to the consideration of the barrels, ammunition, and trials of shooting of the modern sportsman's rifle, occasionally noticing the external details of some typical rifle in each group.

### Barrels.

Most rifle barrels are now made of steel of a specially tough and tenacious quality. Until a few years ago welded barrels were largely used for this purpose, partly on account of their beautiful figure, but mainly because the steel then obtainable was of an uneven, unreliable quality, with varying degrees of hardness, and occasionally so brittle as to fracture under a moderate bursting strain in a most alarming manner. This is now a thing of the past, as steel manufacturers (stimulated, no doubt, by Sir J. Whitworth's great success with his excellent fluid compressed steel) now constantly turn out steel as tough and reliable as can possibly be wished for by any rifle maker. The welded barrels, damascus or other figure, were always subject to imperfections or "greys," defects that seem inseparable from their manufacture, and quite inadmissible in a high-class rifle barrel. The great difficulty also experienced in obtaining a welded barrel of small calibre "clear" in the bore adds no little to the cost of figured rifle barrels. With regard to the double barrelled rifles, the manufacturing processes to which a pair of these barrels are subjected differ in no essential point from those described in Chap. IV. of my first volume in treating upon shot gun barrels, though in the "putting together" process some extra care is required in determining to what extent the tubes shall incline towards each other from breech to muzzle, taking care that each tube be truly straight during its whole length. There is no process upon which the ultimate perfection of the weapon so much depends as this one of "putting together." The angle of inclination towards each other for each particular calibre and weight of barrel, taken with due regard to the charge of powder and weight of bullet to be used—having been previously ascertained by careful experiment—every precaution should be taken by the workman, so that when the operation is completed each tube of the pair should be as straight as when single, and the determined point of impact of each tube when fired with its proper charge be as nearly as possible coincident. We all know that an expert "regulator" can so alter and manipulate a pair of badly put together rifle barrels as to obtain fair, and sometimes good results, but, apart from the question of unequal wear, &c., upon a "sprung" tube, the result can be but a compromise, some of the best points of the rifle being sure to suffer more or less.

### RIFLING.

In approaching the question of rifling or grooving the barrels for the purpose of spinning the bullet, and thereby insuring its approximately true flight through the air, I am aware that I touch upon a vexed question, nearly every rifle maker of note having a particular shape of groove, and some also a special kind of twist, for which they each claim some marked superiority in results over all other methods. My investigations into this matter, both by experiment and inquiry, have resulted in a rather satisfactory conclusion for the practical sportsmen, that is, that equal quality of workmanship and finish give very nearly equal results with most methods of riflings now in vogue; though in some slight degree, in certain special cases, one method may be superior to others. But this superiority is sometimes counterbalanced by some other slight disadvantage. Any method of rifling barrels must be largely influenced by the ammunition to be used and the conditions of using; and as, for sporting purposes, the rule is to employ, in proportion to calibre, rather light bullets and heavy powder charges (for all but small game rifles), we must expect quite a different style of groove from that of the highly-accurate target rifle, whose ammunition is constructed upon opposite proportions: *i.e.*, heavy bullets and moderately light powder charges. We must also take into consideration the conditions under which the sporting rifle is likely to be used, and the necessity of providing for a "rough-and-tumble" life as compared with the carefully-used target rifle. Upon this view of the question, we find most makers of sporting rifles using moderately deep grooves and a comparatively slow twist; in fact, it is generally recognised that, for the purpose of reducing recoil and obtaining a high muzzle velocity, the twist should be as slow as is compatible with accuracy at sporting ranges, while the groove should not be so shallow as to be rendered ineffective by any slight amount of accumulated fouling, or some unavoidable moderate variation in the hardness of the bullets. The groove should, of course, be easily cleaned, and not likely to be seriously damaged by ordinary treatment. In proceeding to examine the leading methods upon which sporting weapons are rifled, I must refer my readers to the accompanying illustrations, which give a fairly accurate idea of each variety, though it is necessary where such small values are dealt with as enter into the grooving of a rifle barrel, to somewhat exaggerate some of the details, so as to enable the eye to sufficiently appreciate them, and hence they do not pretend to indicate the depth of the cut. In all cases the dotted lines represent the original bore. The following plans are selected as those which are now in general use, and are given in the order in which they have been brought out. The sketches are about four times the real size, and in all cases represent the barrel as viewed from the breech end.

## THE ENFIELD RIFLING.

This was originally made with three or five grooves, but is now more frequently employed in a seven-grooved form, with flat sides and concentric bottoms to each, as in the annexed plan. It has been adopted for many years by Mr. Turner, Messrs. Tolly, of Birmingham, and others, and until lately by Messrs. Holland, of London. When used with the special ammunition of the last-named firm it gave very satisfactory results, though they now adopt a different method, to be presently described; but, as might be expected upon an examination of this method of grooving, a slight loss most probably occurs in the matter of recoil and trajectory. This plan of grooving, in its essential feature, has been largely before the public for the last twenty years, it being identical in principle with that used in the Government Enfield and Snider rifles—the chief peculiarity being what is called a "progressive cut," or a gradual increase in depth of groove from muzzle to breech—not, as in the "Henry," for a short distance near the breech only, but for the entire length of the barrel. The variation of depth of groove at breech and muzzle respectively can be regulated to suit the requirements of the ammunition or the fancy of the maker, who, by allowing a moderate depth of groove at breech to die out, as it were, towards the muzzle,

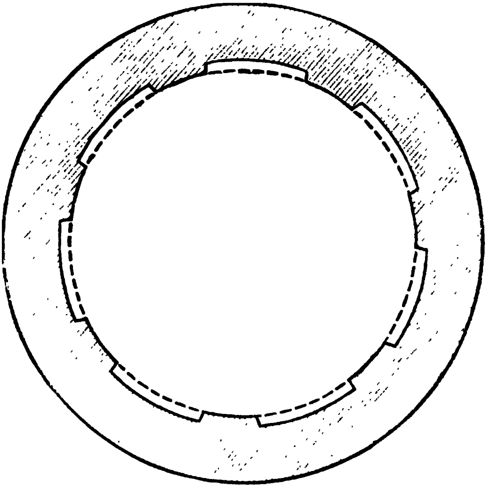


FIG. 20. ENFIELD RIFLING, AS NOW USED FOR SPORTING RIFLES.

thereby produces the "semi-smooth" style of rifling As might be expected from our experience of the shooting made by the Snider rifle, especially at sporting ranges, this method of rifling gives very satisfactory results, provided a projectile resembling the Snider bullet be used, that is, a short, more or less hollow bullet, unpatched, and cannelured, with its exterior well lubricated with grease or wax, or some compound containing these anti-frictional substances. With a solid projectile, if of any length, we may expect that the increasing friction met with in passing every inch of the entire length of the barrel would have a detrimental effect; neither would a similar paper covered bullet work well under such exacting circumstances. The manufacturing details employed in this system of grooving are rather more complicated than usual, and it is found difficult to correct or modify any small defect in the grooving (such as a slight bruise, scratch, or rust spot) inflicted subsequent to the cutting of the barrel in the rifling process, which may account for the system not being generally popular among sporting rifle makers.

## THE LANCASTER OVAL BORE.

The so-called "oval bore," introduced some thirty years ago by Mr. C. Lancaster as a suitable groove for the ·500 calibre muzzle loader, has been adapted to sporting rifles mainly by his successors in business, and, judging from report, with a fair amount of success. I have described in the *Field* some good results in point of accuracy from a ·500 calibre Express single rifle, but I am unable to verify any performances made with other calibres rifled on this system, which was largely used by the Government for military arms at one time, but has been discontinued by them for a number of years. The peculiarity of this rifling is that the interior of the barrel has two bold grooves cut opposite to each other and formed without any rib or edge, so that the barrel has obviously an oval appearance (see Fig. 21). This absence of corners, such as exist in other styles of groove, certainly facilitates cleaning, and reduces the liability to injury from bruising, &c., when that operation is carelessly performed. On the other hand, the great obliquity of the bearing side of the groove used in imparting rotation to the bullet during its passage, seems to me to be calculated to set up unnecessary friction, resulting in diminished muzzle speed and increase in trajectory curve.

There is also an objection of some weight against all methods of rifling that have an *equal* or even number of grooves, thus throwing two grooves opposite each other; this objection is not of much moment in a rifle in which the conditions permit a shallow groove; but in the Lancaster system the grooves cannot be shallow. Thus a bullet to give accurate results must quite fill up the entire depth of both grooves the instant of firing; and to insure this an amount of forcing is resorted to by increased diameter of bullet as compared with the calibre of barrel not in accordance with modern axioms received by rifle makers. This plan is most usually rifled upon an increasing pitch of spiral gaining in rapidity towards the muzzle and combined with a more or less progressive depth of groove from muzzle to breech.

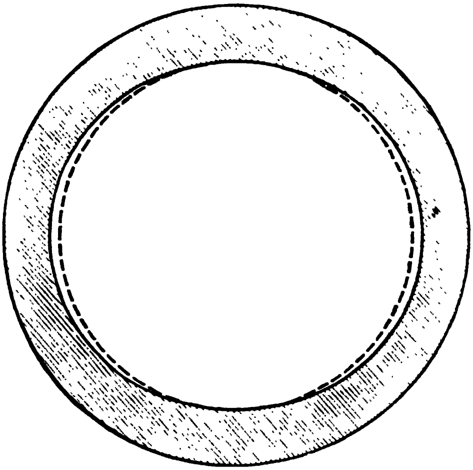


Fig. 21. C. Lancaster's Oval Bore Rifling.

I have already observed that in my opinion there is little advantage in any of the various methods of rifling now in use as compared with their rivals, but as "Mr. C. Lancaster" claims a good deal, and as his claims have been endorsed by many of the correspondents of *The Field,* I insert his description *in extenso,* with the obvious conclusion that, according to the above statement, I do not endorse them as fully as he could wish.

### CHARLES LANCASTER'S NON-FOULING ELLIPTIC OR SMOOTH OVAL-BORE RIFLING.

The Lancaster oval-bore is a modification (as far as the principle is concerned) of the 2-grooved, but at the same time a modification that obviates all the objections to which that system was open. The method of construction is as follows: The barrel is bored perfectly cylindrical, ready to receive the frame that carries the cutter, by which the bore is increased on two sides, so giving a major and minor axis in one and the same tube, and making the barrel oval in the bore instead of cylindrical, which oval form turns spirally the whole length of the barrel, and the bullet, when forced through the barrel, necessarily gets a rotatory motion on its own axis. The great object to be obtained in a rifle is accuracy with the flattest possible trajectory. This is only to be obtained by a high velocity for the ball during its passage over a given distance. The initial velocity of the ball depends upon the burning of so much powder in the barrels. The accuracy of the ball's flight depends upon its rotatory motion, that rotatory motion is imparted by the grooving of the rifle in most cases, and by the oval-bore in the Lancaster system.

With a given amount of powder, the smaller the resistance to the ball in passing through the barrel, the greater will be its initial velocity on leaving it. The grooves on the inside of a barrel naturally prove a greater resistance than a smooth surface, therefore the smooth surface of a Lancaster barrel gives less resistance than any grooved barrel, and for a given amount of powder, the initial velocity of the ball must be greater and the recoil less.

The ball having left the rifle, the great object is to keep up its velocity to the highest possible pitch for the sake of a flat trajectory, and to keep up its rotatory motion for the sake of accuracy. The etarding forces opposed to the attainment of this object, are the resistance of the air and the friction of the air on the rotating ball therefore, the smoother the ball the less friction or retardation there will be.

In the case of the Lancaster oval-bore, the ball leaves the barrel with a smooth surface, while in grooved rifles, it is more or less jagged and indented by the grooves, therefore, with a given amount of rotary motion on leaving the barrel, the Lancaster ball will keep up that motion longer than a ball from a grooved barrel, and would, therefore, give greater accuracy along the whole length of its flight.

But, having shown that for a given amount of powder the initial velocity of the Lancaster ball must be greater than that from a grooved rifle, and also that after leaving the barrel it meets with less resistance than a ball from a grooved rifle, therefore it has a flatter trajectory, greater accuracy and less recoil, hence its superiority.

I append herewith a trial of a Lancaster smooth oval-bore Express rifle which took place before the Editor of the *Field* on Feb. 12 at Wormwood Scrubbs, report of which appeared in the *Field* of the 17th Feb. 1883:—

"On Monday morning last, after several adjournments owing to the weather, we proceeded to Mr. C. Lancaster's ground at Wormwood Scrubs, with a view to witness a trial of one of his oval bores, which we have been requested to do by several correspondents. The morning was by no means favourable to good shooting; indeed, the wind was so high as to tax the strength of the shooter in keeping the barrel steady. It blew from the right front of the range, and occasionally with great force, with a few drops of rain, which necessitated an umbrella being held over the front sight.

"The rifle was a single ·500 oval bore, with Mr. Field's action, weight 10lb. 6oz., length of barrel 26in. We began with a series of ten shots, with 160 gr. C. and H. No. 6, and 600gr. pure lead bullet, having a cavity in front, $\frac{1}{16}$in. in diameter, and half the bullet; distance 100 yards.

"First eight shots were grouped in a space of 5in. × 4in., the ninth 1½in., and the tenth 4in. to leeward of the group.

"Second series.—Powder, 160gr.; lead, 440gr. pure soft lead, with a cavity in front filled with wax. Eight shots were fired, of which the first six were in a group 3½in. square; the seventh was 6in. from the centre of this group to the top right. Mr. C. Lancaster, having previously stated that he was hitherto making no allowance for wind, now declared to make a bull (1½in.) by allowing for wind, and did so, the barrel not being wiped out during the trial.

"This performance, even without taking into consideration the gusts of wind which were blowing, is a very good one, but making allowance for this drawback, our readers will, we think, agree with us that it was highly satisfactory to Mr. C. Lancaster, who, besides being the maker, shot the rifle himself.

"The initial velocity of the heavy bullet was about 1620 feet per second, and that of the lighter one 1750ft., as taken by the chronograph belonging to Messrs Curtis and Harvey; consequently, there should be a difference of about 1in. in the elevation of the two at 100 yards on this calculation, yet in practice, though Mr. C. Lancaster took the same sight throughout, they were as nearly as possible alike, which can only be accounted for by the greater 'jump' given by the heavier ball. This is a very interesting fact in support of the 'jump' theory."

The introduction of the breech system of loading a rifle has done more to perfect the oval-bore and its performances than perhaps any other system of rifling, because, when used with a muzzle-loading rifle a certain amount of windage had to be allowed to facilitate the passing of the bullet down the barrel on to the wad over powder charge; consequently a wild shot was sometimes obtained owing to the stripping of the bullet, which bullet was in those days of an ovoid form, and care had to be taken to get the bullet into the oval or major axis of the barrel in loading. The introduction of breech-loading arms has enabled the major axis or oval to be very much nearer in size to the minor axis or cylindrical portion of barrel, thereby considerably reducing the friction and possibility of a jam, which sometimes occurred in the rifles where both the barrel and the bullet were ovoid. The bullets are now perfectly cylindrical and conical at the front, and made on the very best principles of Express patterns, so as to obtain the very best results. Their diameter is regulated to that of the bore of the rifles which is made in all sizes from ·230 to ·577, and also from 20 to 4 bore for large game. In either case its lateral expansion at the moment the rifle is fired, is enough to compel it to fill the barrel perfectly; in fact, to seal the tube hermetically till the projectile has left the muzzle, and so obtain its rotatory motion from the spiral ovoid. The bore being as smooth as that of a shot gun, it can be more easily cleaned than a grooved barrel, also as there are no grooves, shot can be used from rook rifles, thereby making them useful for collecting small birds abroad, and also from the larger bores in cases of emergency, where the "pot" has sometimes to be filled in hunting expeditions.

Bullets may be made either of soft pure lead, or may be hardened down to $\frac{1}{10}$th of tin.

It will be seen in the above description that "Mr. C. Lancaster" claims a greater muzzle velocity in proportion to the powder used than can be obtained from other forms of grooving. According to the Enfield trials of the military arm this has not been shown, and even taking Messrs. Curtis and Harvey's report of the velocity of the ·500 bore, as recorded at page 250, a muzzle velocity of 1750 feet per second only was obtained with 160 grs. powder to 440 grs. lead, rather more than 1 to 3, which is as nearly as may be the same as that given at the *Field* trials of 1883 by other rifles.

## THE HENRY RIFLING.

Fig. 22 represents a ·450 express rifle barrel grooved on the "Henry" system. Certainly more sporting rifles in this country have been grooved on this system than any other, especially the small and medium calibres, probably on account of its adoption by the Government in 1868, though this pattern groove was then selected on account of its suitability for a long-range military weapon carrying a heavy

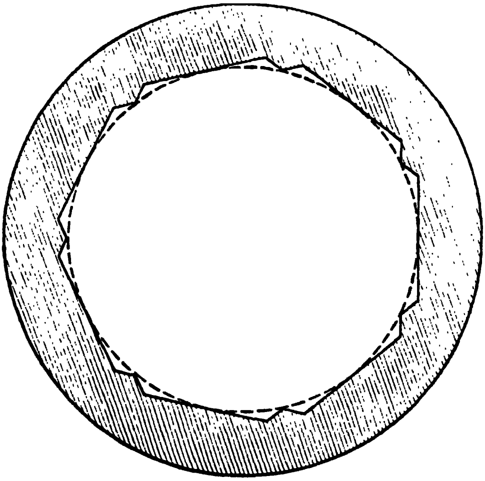


FIG. 22. HENRY'S RIFLING.

bullet and moderate powder charge. As will be seen, there are seven grooves, each with a rib or "re-entering angle" filling up what would otherwise be the deepest part of the cut. Sometimes this pattern is made with nine grooves, especially in larger calibres than the ·450. Since its first introduction an important practical modification has been incorporated with this system, which is somewhat difficult to describe; that is, for some inches from the breech end the groove gradually deepens toward the breech, so that the calibre is widest at that end of the barrel, the effect being, that on firing the cartridge the bullet expands to the wide part, and gradually tightens as it passes onwards until it gets about one-quarter way up the barrel, whence up to the muzzle the depth of cut is uniform. This rather difficult mechanical process seems to be so necessary to the correct performance of the "Henry" barrel, that few are made otherwise, though in his original specification the patentee seems unaware of its importance. In a patent for "rifling barrels," dated 1860, by Mr. Turner, of Birmingham, we find this identical improvement described, also the tools, &c., necessary to carry it out. The twist of this rifling in a ·450 Express is uniform in spiral, and a complete revolution, in all the specimens I have examined, is made in from 30 to 35 inches. It appears necessary in this method of grooving to keep the calibre of the barrel *small* in comparison to the diameter of the bullet, showing that neither expansion, or what is termed "upset," is entirely relied on for securing the complete engagement of the groovings by the bullet.

## THE METFORD RIFLING.

Fig. 23 represents a barrel, ·450 Express, rifled on the Metford principle. This method is chiefly used by the firms of Gibbs, of Bristol, and Westley-Richards and Co., of Birmingham, and has not as yet come into very general use. Though various forms of groove have been sanctioned from time to time by the inventor, the annexed figure gives a fair representation of the latest pattern or one of them. As far as shape goes it will remind old sportsmen of the cut recommended by Forsyth for 12-bore rifles some fifteen years or more ago. The great distinguishing feature of the Metford system is the varying curve of its spiral, starting slowly at the breech end of barrel (say one turn in six feet) and increasing according to a definite law based on the increasing effect produced by the powder gas, which law the inventor claims to have discovered; so that at the muzzle the terminal twist in a ·450 Express will be about one turn in 25 or 30 inches. This constantly varying curve necessitates a patched or paper covered bullet, as the friction on a naked projectile would be considerable from its constant change of form; and in a properly proportioned barrel and its relative bullet, the inventor claims that the effect of the changes of pitch are but just enough to fully shear the paper envelope of bullet without permitting any material injury to its actual surface. Whether any real

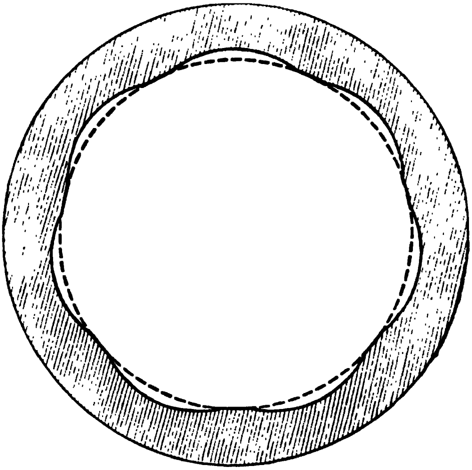


Fig. 23. Metford Rifling.

actual advantage exists in rifling sporting arms on this system has not as yet been made manifest, though, as will be shown under its proper division, there can be no doubt that the Metford system applied to long range target rifles has done good work.

### THE RIGBY RIFLING.

Mr. Rigby adopts a groove of the annexed shape (see Fig. 24), but with a very shallow cut, varying from ·005 inch to ·003—and of the same spiral throughout. In his sporting rifles the cut is even more shallow than in his match rifling, which will hereafter be described. In the Rigby sporting rifles the groove is three times the width of the lands.

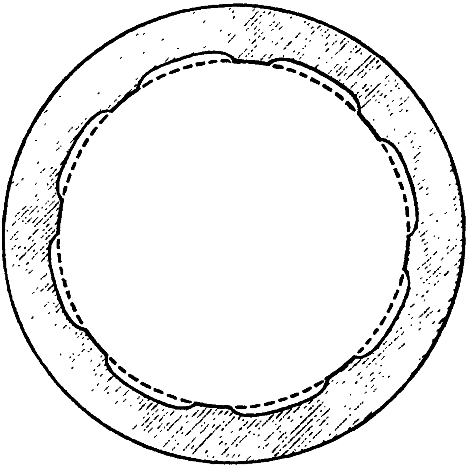


FIG. 24. THE RIGBY RIFLING.

### HOLLANDS' PRESENT RIFLING.

Messrs. Holland have handed me the annexed section (Fig. 25) of the rifling they now use, with which they employ the same smooth plan as to depth, alluded to at page 244.

It will be seen that it closely resembles Mr. Rigby's, and it is also very nearly allied to that adopted by Messrs. Webley, of Birmingham, described below.

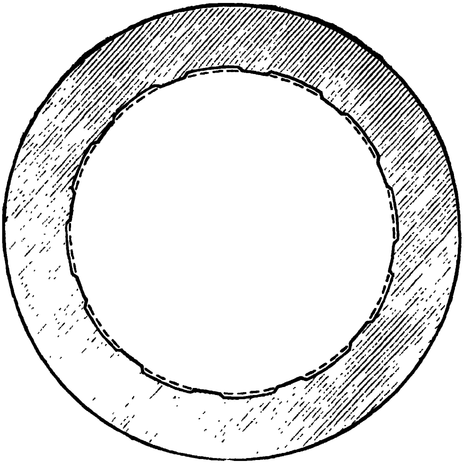


FIG. 25. RIFLING OF HOLLAND'S ·450 EXPRESS.

### MESSRS. WEBLEY'S RIFLING.

This plan has for some time been adopted by Messrs. Webley and Son, who are well known as large wholesale rifle makers, and whose target rifles I shall hereafter notice in the section devoted to that class of weapon. This rifling is

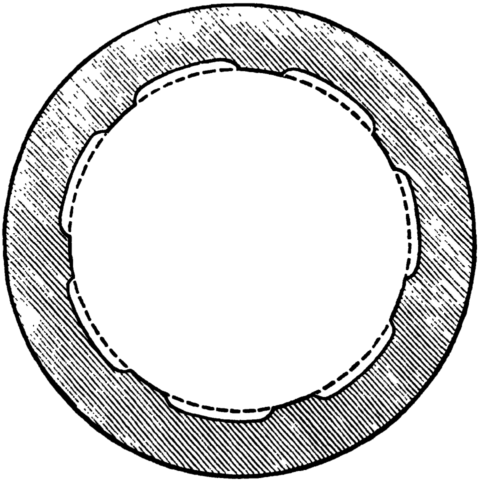


FIG. 26. WEBLEY'S RIFLING.

cut with an uniform twist of spiral, the pitch or amount of turn in a given length of barrel varying in different calibres in accordance with the diameter and length of bullet. The noticeable feature in this plan of grooving, is, that not only is the groove a little deeper at the breech end than at the point several inches nearer the muzzle, but, from the shape of cutting tool it is also a little wider, the object being, no doubt, to insure the grip or engagement of the rifling upon the bullet without any undue forcing of the latter. This is obtained, I am informed, to a most satisfactory extent, as is shown by the use of a calibre of barrel very much nearer the actual diameter of the patched bullet than is usually practicable with some other methods of grooving.

There are numerous other methods of grooving rifle barrels used by different rifle makers, but the examples I have given illustrate the main features of nearly every important type. In large bore rifles, such as 12, 10, 8 and 4 bores, generally used with spherical bullets only, a number of grooves (from 9 to 15, as the case may be), similar in shape somewhat to Fig. 20, with narrow lands, but cut of uniform depth from breech to muzzle, are generally preferred, so as to insure a reliable grip on the periphery of the spherical ball which can only take the rifling by a narrow zone, unless much upset and disfigured by the explosion.

It will be seen by my readers that each plan of grooving I have described displays nearly in every case the anxiety of the maker to insure the bullet "taking" the rifling, as it is called, immediately on leaving the cartridge. There is also apparent a general desire to cause the bullet to tighten its fit in the barrel during its passage outwards, thus continuing to seal the joint, as it were, and prevent the powder gas, at its exceedingly high pressure, from passing it, until it is discharged from the weapon. In some instances an endeavour is made to lessen the recoil by reducing the pitch of spiral toward the point at which the bullet enters the grooving; and, in fact, it will be seen that considerable mechanical ingenuity and research have been brought to bear on this apparently simple, but most important detail of rifle construction.

# CHAPTER II.

## SPORTING DOUBLE EXPRESS RIFLES.

In the present day Express rifles have almost completely superseded all other rifles for general sporting purposes, many good sportsmen considering that they are fully equal to bringing down the elephant and rhinoceros if fairly aimed at the brain of either of these animals, which their great accuracy enables the hunter to do with almost absolute certainty. From the enormous velocity given to the ball, and its hollow shape, the lead is made to spread out on striking a hard body such as bone, and, continuing to rotate with velocity, it tears a large hole in the interior of the chest if aimed at that part, or in the brain, as the case may be, and thus destroys life instantaneously. In this power it resembles the shell, which was relied on by Capt. Forsyth for the same purpose; and not being liable to the accidental bursting in the barrel—to which the shell is sometimes prone—it is by so much the superior, and consequently it has superseded the shell in India and Africa, where this was formerly in general use. With the aid of the gentlemen mentioned at page 10, I have been enabled to define the limit within which an Express may be said to exist, and it is therefore needless to return to the subject here. It is now necessary to describe the bores in general use, the length of barrel best suited to each, and the weight of the whole weapon when put into the sportsman's hands.

### EXPRESS BORES.

The bores now almost universally adopted are ·400, specially recommended by Sir H. Halford for deerstalking; ·450, in general use for that purpose; ·500, more especially adapted for dangerous game; and ·577, which is only suited to those who can bear a very heavy recoil, but in their hands is no doubt a still more fatal weapon than the ·500 bore.

### LENGTH OF BARREL.

The length of double-barrelled Expresses is on the average 27 inches, but different makers adopt slight variations in this length.

### WEIGHT.

The total weight for ·400 bores is usually about from 7lb. to 8lb.; ·450, 8lb. to 9lb.; ·500, 9lb. to 10lb.; and ·577, 10lb. to 12lb.; but, as in the length, so here some variations occur in the hands of different makers.

### CHARGES USED WITH THE VARIOUS BORES.

For Express velocities the general rule may be laid down that at least 1 of powder to 4 of lead must be employed. This proportion is sometimes increased up to 1 powder to 2 of lead—or nearly so. Those actually in use will be found given in a table of loads under the head of Ammunition.

Though, as I have previously remarked, nearly every kind of breech action described in Vol. I. may be used in the construction of a double Express rifle, still as a rule, for some considerable time, rifle-makers have almost unanimously preferred the kind of action known as the "double grip," illustrated and described at p. 144, Vol. I. This preference has been justified by the undoubted soundness and capacity for resisting wear and tear shown by this kind of breech action, besides its great advantages for rifle purposes over most styles of snap actions in the matter of the "draw" or screw-like action of the grip lever in firmly closing the barrels down to their place upon the breech, even against the resistance of a cartridge that is moderately refractory. When this breech action is made with the extended rib or "doll's head," as described in pp. 156 to 160 in Vol. I., it displays, in addition to the advantages there enumerated as belonging to this mode of construction, the additional feature of affording a point of resistance to the "twist," or lateral tendency the barrels have to move in the breech, in consequence of first one barrel being fired and then the other. The value of the extension in thus steadying the side strain in a rifle that fires very heavy charges is not to be over-estimated. The accompanying illustration (Fig. 27) shows a double rifle

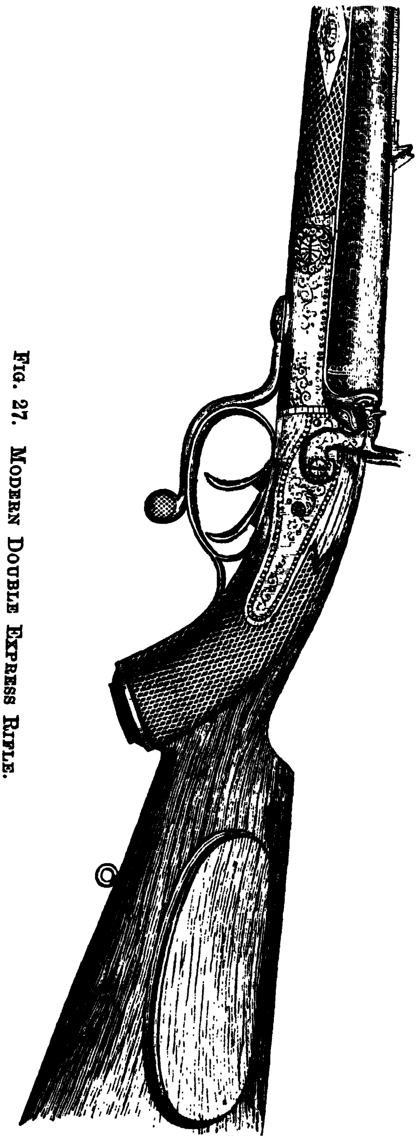
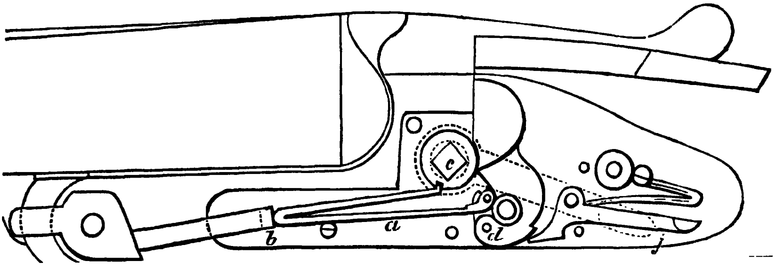


Fig. 27. Modern Double Express Rifle.

having this breech action, together with those almost invariable features in such weapons as the "pistol grip" and "cheek piece," both being modifications of the usual shape of the ordinary gun stocks, and supposed to be peculiarly suitable to rifles for sporting purposes. The utility of the pistol grip is very generally admitted, as it not only allows the firer the better to sustain the recoil of the piece by firmly drawing it to his shoulder, but it brings the finger into a good position for using the triggers. As to the utility of the cheek piece, opinions are somewhat divided. Probably for rifles firing moderate or light charges this form of stock would offer some slight advantage; but with rifles that recoil sharply the stock must be "cast off" to an undue extent to permit the introduction of the cheek piece, and too much cast off is a fault in a rifle stock for obvious reasons. The extra workmanship involved in this rather ornamental excrescence upon a gun stock has probably led to its continued use as a quality mark, or an indication that a rifle is of a rather superior style of finish.

Since Chap. VII., Vol. I., was written, sundry novelties in hammerless gun actions have been introduced, one of the most noticeable here being Messrs. Webley's "positively safe" hammerless action, as it is called, which, when used in combination with that firm's "screw grip" holding-down arrangement shown at p. 224E, in Vol. I., is calculated to be peculiarly suitable for double rifles, though it is also applicable to shot guns. As will be guessed from the name applied, the distinguishing feature in this breech action is the arrangement for insuring safety, which my readers will be able fully understand from the following description and illustrations.

All the safety contrivances hitherto brought forward are on one main general principle, namely—given a tumbler urged forward by a mainspring, and held by a scear, to



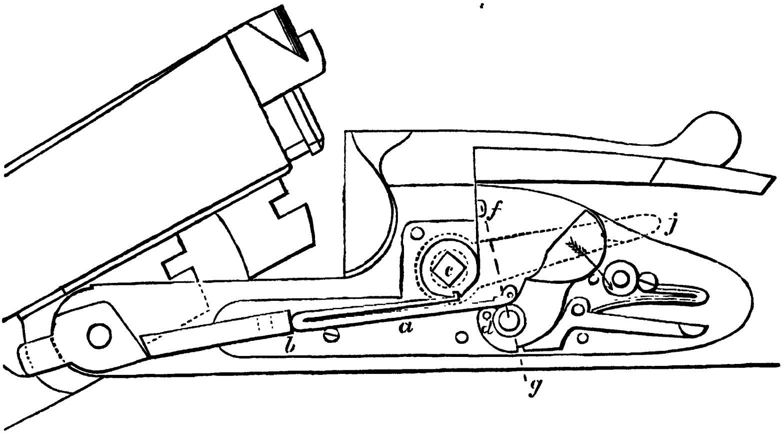


Fig. 29.

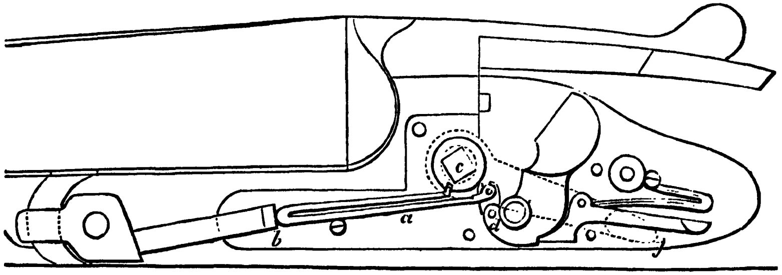


Fig. 30.

Messrs. P. Webley & Son's "Positively Safe" Hammerless Breech Action.

interpose some safeguard against the firing action of the tumbler, in case of its accidental release from the scear. To no one has it seemed to occur that it was possible to construct a hammerless action that should be safe *per se,* irrespective of any safety catches, until intended to be fired. In the arrangement under our notice this desirable result is obtained in a most simple manner, the mechanism being so arranged that, until the user wishes to fire the weapon, the pressure of the mainspring is forcing the tumbler hammer *backwards,* in a direction contrary to that needful for firing; thus, the arm is "positively" safe, and not "negatively" so, by reason of the interposition of extraneous stops and catches. A reference to the annexed figures will show how simply this is carried out. Figs. 28, 29, and 30, show the firing mechanism in three positions. Fig. 28 showing the mainspring released, and the tumbler in the "fired" position. Fig. 29 shows the mechanism "cocked" by the opening of the breech action. Fig. 30 shows the same ready for firing.

The mechanism being in the position shown in Fig. 28, the dropping of the barrels brings it into the position shown in Fig. 29, where the mainspring is shown thrust backward from its abutment at (*b*) pushing before it at its swivel end (*d*), the tumbler, until the latter is at full cock.

The force exerted now by the mainspring is very slight, and is applied to the tumbler *behind* the dotted line (*f g*), thus forcing the tumbler in the direction of the arrow.

While the lock is in this state the scear may be removed from contact with the tumbler with perfect safety. Therefore, while in other breech-action locks the pressure of the mainspring upon the tumbler at full cock is the primary source of danger, needing the check of safety appliances, this very pressure affords the most positive means of safety in this arrangement, because the tendency of the tumbler is *from,* not *towards* the firing pin or striker. It is *impossible* for this gun to be fired in the act of closing.

It will be noticed that the mainspring engages with the disc (*c*) by the small projection at one end of its shorter side; thus, as it slides it causes the disc to turn on its centre, and the outside lever or thumb-piece (*j*), being attached to the disc, moves with it. This lever gives the user control over the mainspring, and also acts as an indicator. To fire the gun, the disc (*c*) is turned by depressing the outside lever (*j*), thus placing the lock in the position shown in Fig. 30. Here it will be seen that the mainspring has thus been returned so as to bear upon its abutment (*b*), the swivel (*d*) has assumed a line at right angles to the mainspring, this latter having thus become fully compressed, and its force exerted upon the tumbler at a point *in front* of the dotted line (*f g*), being in the direction proper for firing, when the trigger is pulled in the usual course. An important feature in this lock is that, except at the actual time of firing, the mainspring is in a permanent condition of "*ease*," there being no appreciable strain upon it, whereas the opposite is the case in all bolted or checked safety arrangement.

The squared axis of the outside lever (*j*) passes through and so operates on the disc (*c*) of each lock; thus, after firing one barrel, the other lock can be put back into the position of safety shown in Fig. 29 by raising the lever. In the same way if, after preparing to fire, the intention be changed, the locks can be at once restored to the safe position.

I think the simplicity and effectiveness obtained by this mode of constructing lock work, will thoroughly recommend this breech action to the notice of my readers, though I may state that I have not actually tried it.

# CHAPTER III.

## LARGE-BORE RIFLES FOR ELEPHANT SHOOTING.

THESE rifles, which extend from the 12-bore to the 4-bore, are almost invariably used with spherical balls, and are rifled with polygrooves, the shape of which varies a good deal, but is really of little consequence. Some sportsmen still consider these small cannon necessary to insure the bringing down of big game; but the smashing power of the ·577 Express is so great that the majority now rely upon it as perfectly serviceable when properly handled. Still it is necessary here to describe them, for the benefit of those who continue to prefer their use.

No modern sportsmen, however, attempts to dispense altogether with the Express rifle—he only demands a bigger bore in addition to it; and, if he can afford it, the elephant hunter makes up a complete battery of these weapons, from a 4-bore down to a ·450, or even to a ·400 bore. I am not now pretending to give any opinion on this subject, and confine myself to a description of the various rifles in use by the modern sportsman, merely alluding *en passant* to what are the general opinions on it. The 12-bore double rifle usually weighs 11lb. to 13lb., has barrels 26 inches long, and is accurate up to 50 or even 100 yards, but is seldom relied on beyond the former distance. The balls used with it are described under the chapter on ammunition. The 10-bore weighs 12lb. to 14lb., with barrels 26 inches long, and its shooting is similar to that of the 12-bore.

The 8-bore double rifle usually weighs 16lb. to 18lb., and has barrels 24in. long. It is used with a spherical ball, and is not to be relied on for accuracy much beyond 50 yards.

The 4-bore double rifle weighs from 20lb. to 24lb., with barrels about 22in. long, and, like the 8-bore, is only used for spherical balls. It also is only sighted for 50 yards.

# CHAPTER IV.

## SINGLE SPORTING RIFLES OTHER THAN ROOK RIFLES.

THESE are made either on the Express or long-range principle, the latter being chiefly used in South Africa, where herds of deer, &c., are often shot at from 300 to 500 yards. The actions used are similar to those employed for match rifles, to be hereafter described, and one of which will answer as well for a sporting weapon. They include the Snider, the Farquharson, Field, Deeley-Edge, Webley-Wyley, Rigby, and Fraser of this country, as well as the Remington and Sharp of America. The Remington is so liable to blow open, especially with Express charges of powder, that I should scarcely recommend it as an action suitable for a sportsman; but all the others above mentioned may be used with perfect safety.

Fig. 31 shows the sectional appearance of a single sporting rifle with Mr. Field's breech action, which is, perhaps, one of the most commonly used in this country for rifles of this kind, when these are required to possess actions enabling the barrel to be wiped out and inspected from the breech end. This is considered to be a most valuable feature in the design of a modern breech-loader by every rifle maker, though the Government steadily refuse to recognise or apply such a mode of construction to the service weapon, preferring that all the wear and tear of cleaning the barrel shall fall upon that portion most essentially necessary to accurate shooting,

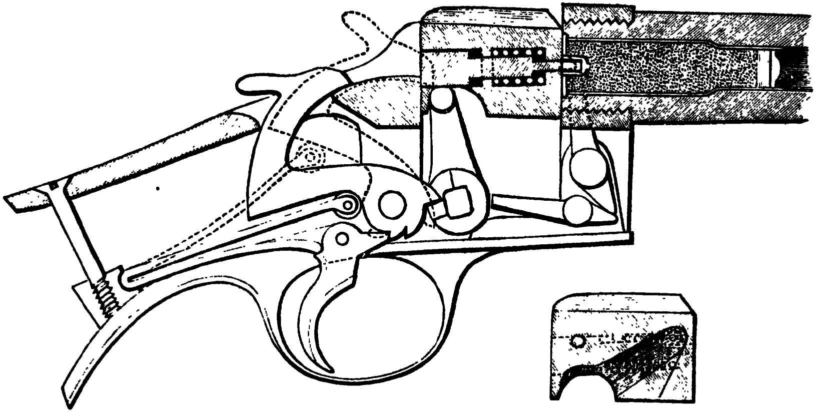


FIG 31. SECTION OF THE FIELD RIFLE ACTION.

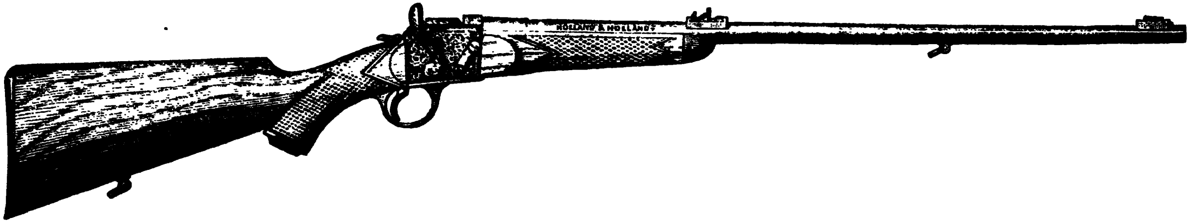


FIG. 32. EXTERNAL VIEW OF THE FIELD RIFLE.

*i.e.*, the muzzle end of the same. The sectional view of the Field breech-action shows at a glance the mechanical arrangements necessary to the carrying out of the functions required in a tolerably simple and effective manner. The external side lever, or main handle, is operated on by being pushed forward from the user and towards the muzzle; and upon the axle or centre of motion of this lever is attached firmly the duplex internal arm, shown as propping the block up in the firing position. A projection on each side of this arm engages with the inclined slot shown on the side of detached block (a similar slot existing in the opposite side of block); thus, when the arm is carried forward by the motion of the main lever, these studs act upon the lower sides of the inclined slots, drawing the block down until it strikes the extracting levers, and causes the fired shell to be withdrawn. While this movement is taking place, and, indeed, before the block commences to descend, a notch in the body or central portion of the internal arm engages with a projection upon the front or "breast" of the hammer, causing this latter to turn on its axis, until, by engaging with the trigger scear, it arrives at the "full cock" position. The hammer can also be manipulated by the thumb of the firer, presenting, as it does, externally an ordinary "comb" to be used in this manner if desired. The dotted lines show the lock mechanism in the "fired" position, the blow of the hammer exploding the cartridge by means of an ordinary firing pin or "striker," which is withdrawn by a spiral spring into the block after relief from the pressure upon it of the hammer urged by a V mainspring, situated at its rear, and together with the hammer working in the "hand" of the rifle stock. This breech action is simple and strong in its details, and if not containing every feature of excellence insisted upon by some, is still sufficiently popular to be rather largely employed in the construction of the better class of single sporting rifles, as I have before intimated. When a cheaper class of rifle is required, the Martini breech action is employed, so modelled as to make up into a rifle with "pistol grip;" this action, however, will not admit the Express cartridges, and is consequently restricted to some form of solid bullet ammunition, such as the "musket" pattern, or the Government ·577/·450.

Of course, all or most of the breech actions enumerated at the beginning of this chapter are made up by their respective proprietors as sporting rifles, but I reserve my remarks upon them until the Match rifle portion of this volume, as most of them have been originated and designed for that class of weapon.

Fig. 32 shews the external appearance of Mr. Field's rifle.

For some purposes the Express system is adopted, but in that case the rifle is not accurate beyond 250 yards, at the most. Where long-range shooting is required, the Henry rifling is most frequently used, but any of the grooves described hereafter as most applicable to the match rifle will do better work, and it may generally be accepted as a fact, that whatever suits long-range match rifles will be useful to the sportsman who wishes a weapon to be used at herds of deer from distances exceeding those at which the Express rifle can be properly applied.

# CHAPTER V.

## ROOK AND RABBIT RIFLES.

SINGLE RIFLES for rook and rabbit shooting are now made in large numbers, and are sold by all gunmakers at prices varying from 2*l.* 10*s.* to 10*l.* 10*s.* each. They are necessarily of small gauge, to avoid mangling these small bodies, and on that account are seldom larger in the bore than ·300, or at the utmost ·360. Moreover, with larger bullets the danger of wounding labourers working in the fields, and others out of sight of the shooter, is largely increased. The smallest gauge used in England is the ·220, which is that of the well-known Ballard (American) rifle, a very useful little gun for the purpose in view. Almost any action is strong enough for a rook rifle, the powder used rarely exceeding 14grs., and being usually about 10 grs. The central-fire brass case is now invariably employed, and, of course, an extractor is necessary. In the present day one that flips out the empty case is adopted by all those who can afford the extra cost. The Express system is rarely adapted to rook rifles, because accuracy is lost and the body of the bird or rabbit is damaged, while the only advantage is the slightly lower trajectory, which, at the usual distance (50 to 75 yards), is of very little importance.

Messrs. Holland, "C. Lancaster," and Rigby have for some years been the leading makers of these little rifles, but the last-named firm have of late adopted the Ballard (American) in preference to their own make. Annexed is an engraving of "C. Lancaster's" present form of rook rifle, oval bore, together with the sights used with it.

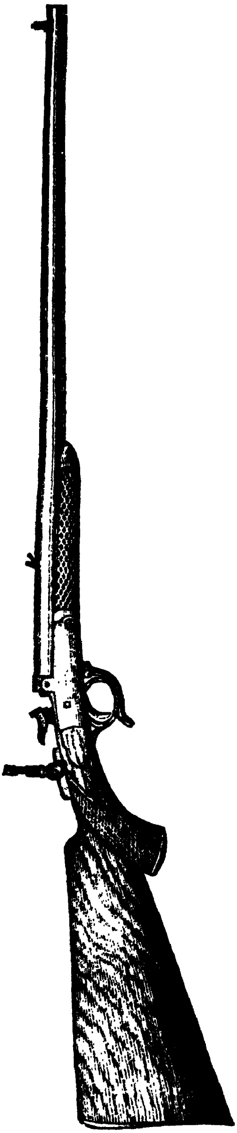
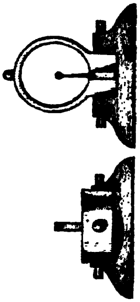
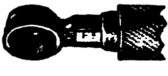


Fig. 33. "C. Lancaster's" Oval-bore Rook Rifle.



FORE SIGHTS, FULL SIZE



APERTURE SHEWING SCALE, FULL SIZE.

## MESSRS. HOLLAND AND HOLLAND'S NEW HAMMERLESS ROOK RIFLE..

A very neat and efficient hammerless rook rifle was invented and brought out about a year ago by Mr. Henry Holland of the above firm. I saw it tried in the spring of 1883, and reported favourably on it in the *Field* of April 14th. Since that time it has become the fashionable rook rifle of the day, and has given great satisfaction to all those who have used it, as far as my experience goes. The following is the report in question—I need scarcely say that the excellent shooting made with its aid has nothing whatever to do with the action, being dependent on the rifling of the barrel, and the subsequent sighting and accurate aiming of Mr. Norman, Messrs. Holland's assistant.

### HOLLAND'S NEW PATENT ·295 HAMMERLESS ROOK RIFLE.

The principle of this action consists in the compressing of the main spring by means of a slotted cylinder, Fig. 34 (*a*) (which is attached to the top lever) acting directly upon the solid projection (*b*), which is forged on and forms a part of the main spring.

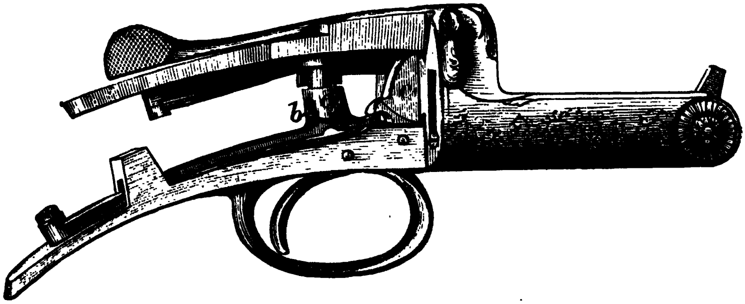


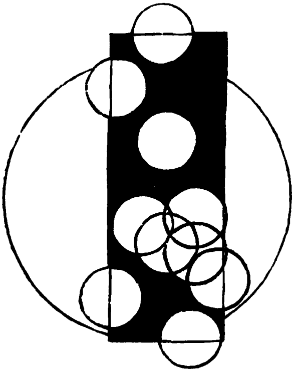
FIG. 34. SECTION OF HOLLAND'S HAMMERLESS ROOK RIFLE.

As the top lever is turned to the right to open the rifle the inclines on the cylinder (*a*) acting upon similar inclines on (*b*), force the mainspring down with a kind of screw motion, and at the same time the hammer-tumbler (*c*) is brought to full cock.

Nothing can be more simple than this plan, and nothing more pleasant in the hand. The appearance of the rifle is also very neat, as will be seen from the view given in Fig. 36.

The rifling grooves are very shallow, and the friction appears to be proportionately reduced, estimating it from the fall between 50 and 75 yards, which apparently is not much more than 1in., as far as can be ascertained by the experiments we have tried. As to its accuracy the 10-shot diagrams here given, which were made consecutively in our presence by Messrs. Holland's assistant on Monday, the 2nd instant, at their Kensal Green range, will speak for themselves, being certainly the best we have ever seen made.

50 Yards.



Full Size.
10 Shots in $\frac{9}{16}$ by $1\frac{5}{8}$ inches.

Fig. 35.

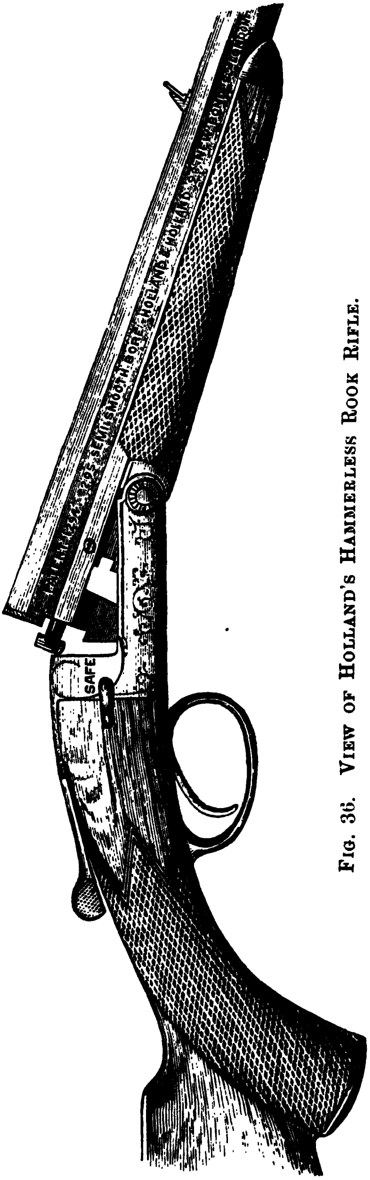


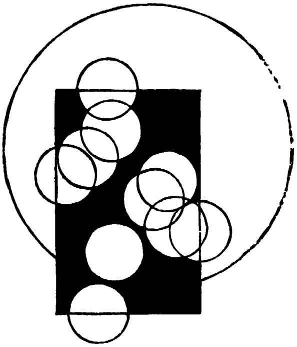
Fig. 36. View of Holland's Hammerless Rook Rifle.

The barrel was not cleaned out after the first shot was fired, and instead of going off its shooting, the last diagram made was actually the best.

In changing from the 50 yards to the 75 yards range, we requested the same sight to be used, and the spot marked with a cross in Fig. 39 to be aimed at. As will be seen, the group of shots shows that the extra fall in the 25 yards is somewhat less than an inch, supposing our instructions to have been carried out, which we have every reason to believe they were.

For rook and rabbit shooting, this ·295 bore is, in our opinion, superior to the ·360. First, in accuracy; secondly, in losing velocity after the desired range is obtained, so that it may be used under circumstances which would forbid the employment of the larger bore; and thirdly, in maintaining its accuracy for an indefinite number of rounds without cleaning out. We may now congratulate Messrs. Holland on having produced a rook and rabbit rifle which completely fulfils all the conditions required by the sportsman, and may be considered an absolutely perfect weapon.

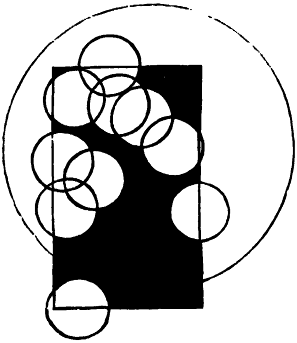
50 Yards.



Full Size.
10 Shots in $\frac{3}{4}$ by $1\frac{3}{16}$ inches.

FIG. 37.

Sporting Sights. 50 Yards.



Full Size.
10 Shots in $\frac{3}{4}$ by $1\frac{1}{4}$ inches.

FIG. 38.

Card targets were used, and were signed by us. At first there was only a light air from the left, but when shooting at 75 yards the wind freshened up from the left sufficiently to affect so small a bullet at that range.

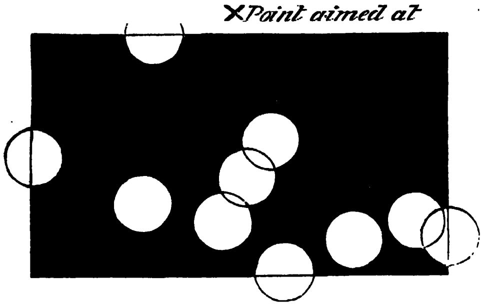
**Summary at 50 Yards Range.**

| | | | | | |
|---|---|---|---|---|---|
| 1st | Series | 10 | Shots, | all in | 1¼in. by 1⅝in., 8 being in 1¼in. square. |
| 2nd | ,, | 10 | ,, | ,, | $\frac{9}{16}$in. by 1⅝in., see Fig. 35. |
| 3rd | ,, | 10 | ,, | ,, | ¾in. by 1$\frac{3}{16}$in., see Fig. 37. |
| 4th | ,, | 10 | ,, | ,, | 1in. by 2½in., 9 in 1in. by 1¾in. |
| 5th | ,, | 10 | ,, | ,, | ¾in. by 1¼in., see Fig. 38. |

The 3rd series were fired with ordinary sporting sights. All the shots would have struck a penny piece. The other series were fired with aperture sights. In each diagram the circle shows the actual size of the bull's eye aimed at. To sum up, out of the 50 shots fired at 50 yards 46 were in a 1½in. square, and 42 were in 1¼in. square.

75 Yards.

10 Shots, all in 1¼in., by 2⅛in., see Fig. 39.



Full Size.

10 Shots in 1¼ by 2⅛ inches.

Fig. 39.

The above rifle is an expensive one, being 10gs., or double that of a good plain hammered rifle as made by the same firm, as well as by others of the same character.

The rifling of rook and rabbit rifles made by different firms, varies slightly in its details, but it generally consists of five, six, or seven shallow grooves, with a very slight twist. I have been favoured by Messrs. Holland with two diagrams of the rifling used by them, which I have had engraved. The depth of cut is exaggerated, as it is so slight as scarcely to be visible, if drawn according to scale. On reference to the rifle trial of 1883, which is hereafter given, it will be seen that Messrs. Holland's rook rifle made diagrams in public of much the same dimensions as the above which were made in private, though not under such favourable circumstances. My own opinion is that in these, as in all other rifles, the principle of the rifling is comparatively of little consequence, the accuracy of shooting depending on the workmanship and final regulation.

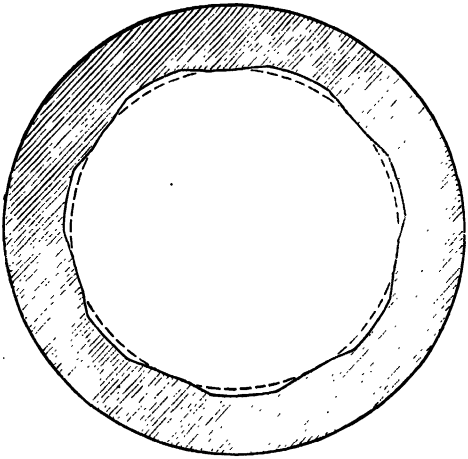


FIG. 40. HOLLAND'S ·295 7-GROOVED ROOK RIFLE.

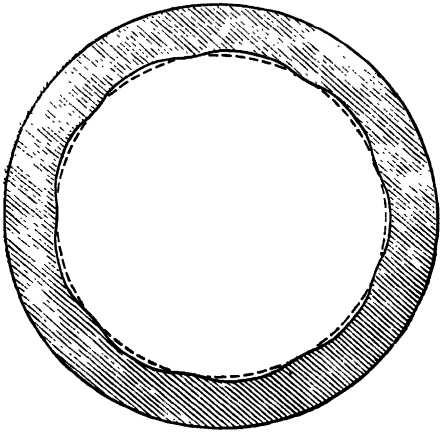


FIG. 41. HOLLAND'S ·295 9-GROOVED ROOK RIFLE.

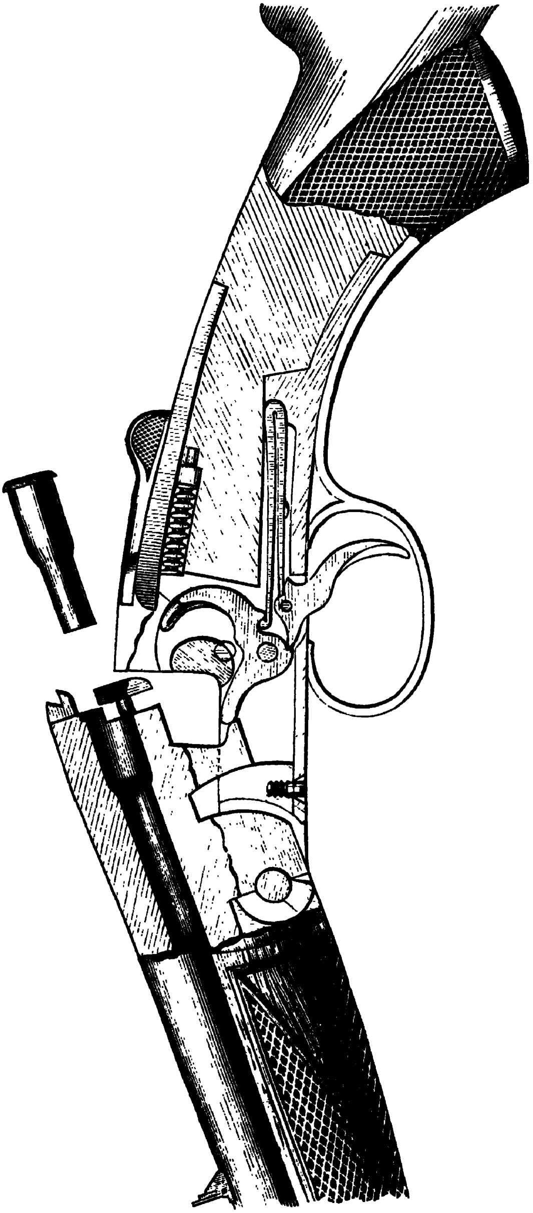


Fig. 42. Mr. Field's Hammerless Rook and Rabbit Rifle.

Another form of hammerless action applied to rook rifles is the one shown in the annexed engraving. It is by Mr. Field, and the cocking is effected by the fall of the barrel, the thumb lever only being used for securing the barrel in its place ready for firing; the sectional illustration (Fig. 42) sufficiently explains the mechanism of this rifle, which appears to be both strong and simple in its details of construction.

### MORRIS'S TUBES.

A plan has been lately introduced by Mr. Morris, by which a tube rifled for a ·230 ball is slipped into a larger bore, which may be either rifled or plain. In this way a 20-bore shot gun, or ·450 or ·500 Express, may be made suitable for rabbits or rooks at a trifling extra expense. A full description of these tubes will be given hereafter under the head of "Match Rifles."

### DOUBLE ROOK RIFLES.

These are sometimes made, and are specially adapted for rabbit shooting, where a second shot is often to be had within the time that a cartridge can be extracted and replaced. Any of the actions for shot guns described in Vol. I. will suffice for the purpose. Of course, there is the extra difficulty in getting the two barrels together to be overcome, and this adds so much to the cost, that few sportsmen care to go to the necessary expense.

# CHAPTER VI.

## COMBINATION RIFLES.

A combination of the rifle and shot gun is made by several firms, and notably by Messrs. Bland, who have entitled it the "Cape Rifle," being intended chiefly for use in South Africa, where all sorts of game are sometimes unexpectedly met with. It is alleged by many sportsmen that the combination spoils the shooting of both barrels, but in a trial of one made by Messrs. Bland, selected by chance out of their stock, I made excellent shooting at 70 and 100 yards with the rifled barrel (·577 bore Henry) and also with the smooth bore, so that I think that objection cannot be maintained, though, of course, the perfect balance and consequent ready handling of a well modelled shot-gun cannot be expected in a weapon so heavy forward, as the additional weight of the rifle barrel causes such a weapon to be. The action is on the ordinary double grip principle.

### Messrs. Silver's Transvaal Rifle.

Messrs. Silver and Co., of Cornhill, also make a rifle which can be used with either a rifled or smooth bore barrel. On this plan each barrel is removable, being screwed into the action as shown on the annexed block. I have not tried the shooting of this, which is called their "Transvaal Rifle," but there is no reason why it should not be up to the high level of the usual work turned out by the above firm. It consists of a stock into which any one of a series of barrels may be screwed, so that it may be used either as a shot gun with a smooth barrel, or with a ·450 or ·577 Express. Fig. 43 shows the stock separated from its barrels, one of which is a rifle and the other a smooth bore.

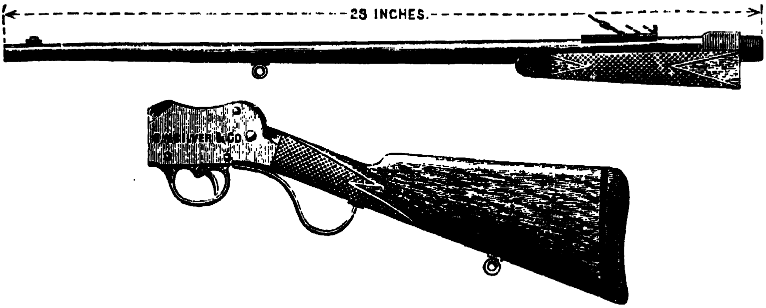


Fig. 43. Messrs. Silver's Transvaal Rifle.

### C. Lancaster's 4 Barrelled Combined Rifle and Gun.

This combination is on the plan described in Vol. I., at page 232, two of the barrels being rifled, and the other two smooth. The plan is especially adapted for the foreign market.

# CHAPTER VII.

## REPEATING OR MAGAZINE RIFLES.

By repeaters is understood a plan by which a rifle may be made to discharge a number of shots, without reloading, the cartridges being contained in a tube which is either in the stock, as in the "Spencer" repeater, or under the barrel as in the Winchester, Henry, and Colt. The Spencer tube only holds 9 cartridges, but the others all contain 12 or 14, though it is far better to charge them with only 10, as the spring soon becomes weak from over compression. The Spencer is quite out of date in this country, and the Henry is superseded by the "Winchester," which, in its turn, is likely to be hard pressed by the "Colt," a recent production of that celebrated factory.

### THE WINCHESTER REPEATER.

Early in the year 1875 I carefully examined and reported on this repeater in *The Field* in the following terms. The opinions I then gave have been subsequently fully confirmed, as the weapon has been to some extent used in all parts of the world, though to British sportsmen accustomed to the high degree of perfection of form and handling attained by rifles of home design and manufacture, there is a sense of awkwardness inseparable from these weapons largely due to their somewhat uncouth outlines, rendered necessary no doubt by the exigences of their construction by machinery. That this disappears in time on becoming familiar with the arm is doubtless true, but there is always *something* different in the handling of a repeater, especially with its magazine charged, that contrasts disadvantageously when compared with a neatly made single or double rifle; and, taking the averages of sporting experiences into consideration, I much question whether the rapidity of fire so much lauded is quite an equivalent, at least with a sportsman trained and accustomed to the latter types of rifle.

The new model central fire Winchester Repeater is the product of long and carefully noted experience (dating from 1858), gained both in warfare and in the sporting fields of America and Canada. As a means of comparison, showing how this arm was developed (or rather its principle), it may be useful to refer back to the period when the revolver—then sometimes termed a repeater—was introduced here through the medium of the first exhibition (1851), by Col. Colt and Messrs Deane and Adams. It was then felt to be an immense advantage to have several shots available instantly for an emergency; and this impression was so true, so well founded, that to this day the revolver, as a portable arm, has never been superseded in its particular line, namely, that of defence. When, however, the principle was called into request for sporting rifles, it failed, for it was found impossible to obtain anything like decent accuracy beyond 80yds. or 100yds.; and even then the best figure of merit was obtained by using a spherical bullet, the conical bullets invariably going wild. This failure in the revolving rifle was owing to the fact that it is mechanically impossible to adjust the chambers so that each bore shall coincide *accurately* with the bore of the barrel at the instant of discharge. No tool can correct this ; the calibre of barrel being two or three sizes less than that of the chambers (in order to make the bullet take the rifling) sufficiently explains the difficulty. The above-named inventors, Col. Colt and Messrs Deane and Adams, each went into the subject and exhausted it, but failed. It was found impossible to insure the axes of the two bores coinciding. The difficulty nearly disappears in a single breechloader, as the bore acts as a guide while the chamber is being cut into it, though not dispensing with the workman's judgment, as he must get it true to his eye during the process. This, however, applies more particularly to the boring of the barrel itself.

The failure of the revolver principle when applied to rifles and

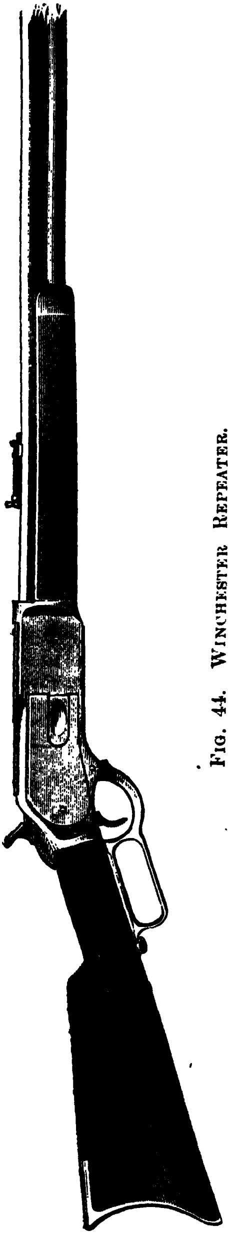


FIG. 44. WINCHESTER REPEATER.

tested for accuracy, no doubt stimulated the manufacture of the repeater. In its early patterns—the Spencer, the Ball and Lamson, and others, including the Henry (American), which Mr. Winchester selected as the then best to base all his projected improvements upon—the mechanism was generally pronounced too complicated. The great fault lay in the difficulty of refilling the magazine; in most cases it necessitated the dismounting of the gun by removal of the magazine, which is almost impracticable under excitement. But this inconvenience was submitted to, from the need felt of some such arm capable of delivering a continuous fire, and with more accuracy than the revolver. The new model Winchester is the result of a long and costly period of experimenting by the Winchester Arms Company, who determined to produce a weapon which should unite the simplicity of a single-loader with the immense advantages of an untouched reserve of, say, fourteen shots, having all the rapidity of a revolver when needed, but equalling in accuracy the best known single-barrelled arm, even up to the very longest ranges that can be commanded with the limited charge of powder and lead. This was not the whole of their aim. It was also determined to reduce the number of working parts, and their arrangement to the simplest possible conditions, and externally to give a compact, handy appearance to the arm. Too much stress can hardly be laid on this point, and the confidence it must afford to the shooter when excited, that, whether the magazine be full or half full, or with only two or three in it, he can instantly suspend his reloading, and either use the few that are in, or load and fire singly. The breech mechanism is a matter of surprise to all from its extreme simplicity. By taking out one screw on the left side of breech the covering plate comes off, showing the action, the connections of which are simply two stud pins, convincing any person that it cannot possibly get out of order. With regard to strength, it may be remarked that all these new model arms pass the London Proof House, and bear the well-known London proof marks—the most severe test that can be applied—but it does not in the slightest degree affect their working.

It may be that this new and undeniably well-designed arm, possessing as it does rapidity, accuracy, long range, and simplicity of parts, will eclipse all single-loaders, even from a military point of view, but at all events it must commend itself to the attention of sportsmen. There are but few who do not appreciate the advantage possessed by a double-barrelled rifle over the very best or most rapid single barrels. The double has its two shots available, while the single, even in the hands of an expert, may, in the act of taking a second cartridge from the pouch, lose a valuable chance. At a target the single breech-loader will, in good hands, deliver twenty or more shots within the minute, but fails entirely to deliver two shots in succession so rapidly and accurately as a double-barrel would do. The thing is impossible ; hence no single will ever supersede a double, whether it be against a charging animal or a flying one.

If this advantage be so patent in an ordinary double, it is clear that something must accrue in the presence of a repeater with its fourteen cartridges already inserted, and therefore available while the animal is in sight. Up to 800 yards the accuracy is said to be remarkably good, but we have tested it at ordinary sporting distances—say 100 yards to begin with—when the whole fourteen shots may be made to touch each other, or nearly. This is as much as the best-known single breech-loader will do ; in fact, the conditions and performances are similar, only that repeater cartridges are inserted in the barrel mechanically, and in single-loaders by hand.

To load : at right hand side of breech is a small trap (see Fig. 44) ; press the point of bullet against this, and push forward the cartridge sharply each time, until the fourteen or any less number are inserted. To fire : Throw down the lever sharply, and close it up again ; then press the trigger. After firing, throw down the lever as before ; this ejects the exploded cartridge shell. Closing up the lever inserts a fresh one. These movements may be as rapid as the hand itself can move, or as slowly as desired; it matters not how; the rate of movement in no degree affects the action. As before mentioned, there is no particular necessity for having the magazine quite full before commencing to fire, neither need it be empty before reloading; and, supposing the magazine to be full, and one shot from it fired, another cartridge may be inserted, and that fired, and so on, leaving the magazine intact for an emergency. The whole fourteen shots can be fired in as many seconds without removing rifle from the shoulder.

Fig. 44 represents the sporting pattern with heavy barrel, for very accurate practice. Weight, 8½lb.; length over all, 3ft. 7½in.; magazine, 14 shots.

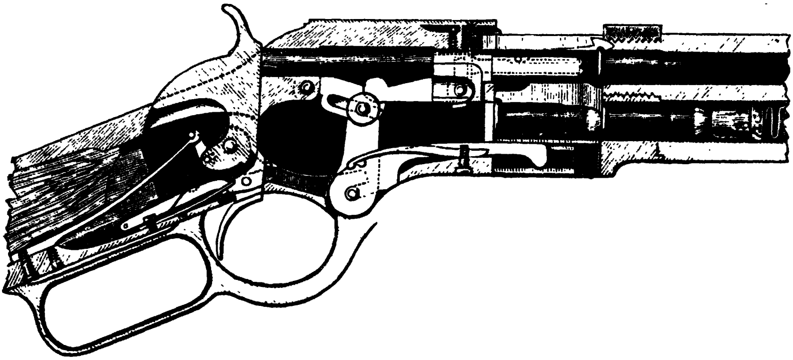


FIG. 45. WINCHESTER REPEATER AFTER FIRING.

Fig. 45 gives a section after firing.

Fig. 46 gives a section with lever depressed.

The agents in London are Messrs. Kerr and Co., 118, Queen Victoria-street, London, E.C.

Since the above report was written, this repeater has been made to take a cartridge on the Express principle, with 80grs. powder and 300grs. lead, but of course with a reduction in the number of cartridges in proportion to the increased length of the Express case.

I have recently seen this repeater shot at Nunhead, under the supervision of Mr. Kerr, both with the Express charge in a ·500-bore, and with that employed for rabbits and rooks in a ·330-bore, each at 100 yards. The former gave very fair diagrams, but not equal to those made with first-class Express English rifles using corresponding charges; but I am inclined to believe that the fault was in some measure independent of the rifles.

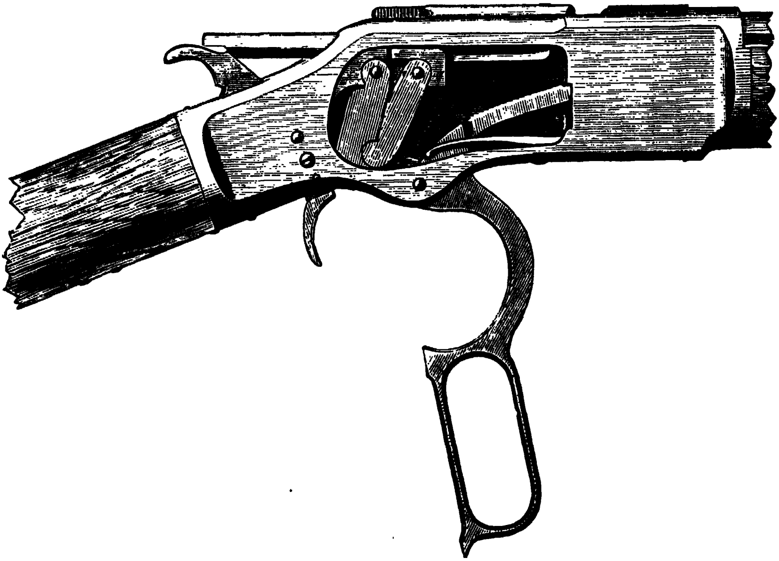


FIG. 46. WINCHESTER REPEATER OPEN.

Of course the Express charge could not be expected to come up in accuracy to that used by Dr. Carver in a smaller bore, and which many of the correspondents of the *Field* have reported on as extremely reliable.

## THE COLT MAGAZINE RIFLE.

The patent for the Winchester Repeater having expired several American firms have brought out modifications of its principle, among which may be mentioned the well-known firm of Colt and Company. Annexed will be found a reduced

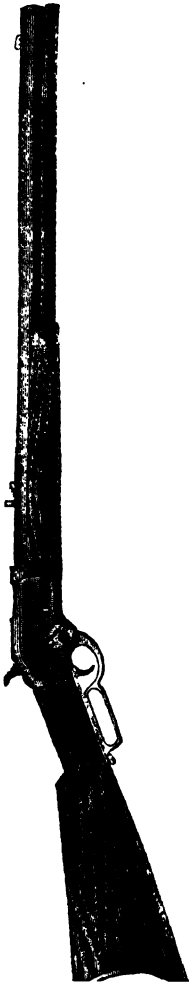


FIG. 47. VIEW OF COLT'S MAGAZINE RIFLE.

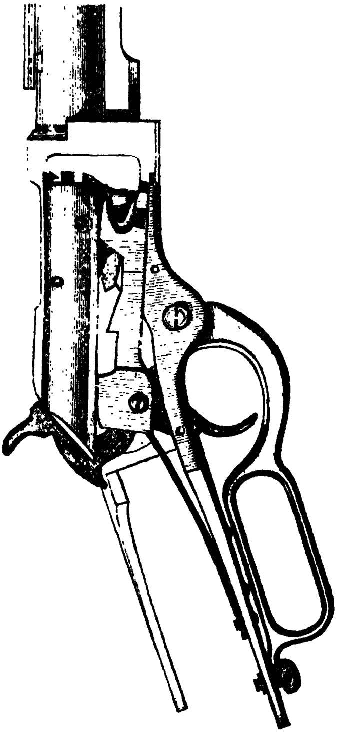


FIG. 48. COLT'S MAGAZINE RIFLE CLOSED.

view of their Magazine Rifle (see Fig. 47), by which will be seen that it closely resembles in external form the Winchester Repeater, as described in the previous pages, Figs. 44, 45, and 46. I have myself shot this rifle at 50 and 100 yards, and made excellent practice with it; indeed, the well-known excellence of the Colt rifling will speak for itself in this matter, and I have simply tested it with a view to ascertain whether its working could be relied on, in which respect I can confidently recommend it. I give sections of the Colt corresponding with those of the Winchester, so that my readers may judge for themselves of the resemblance between them.

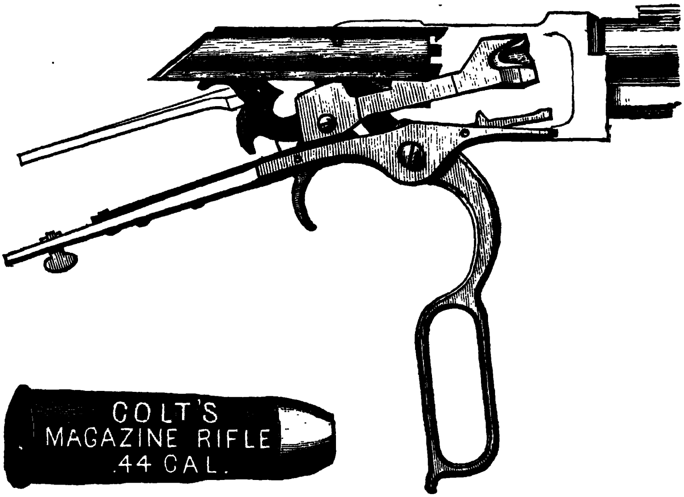


Fig. 49. Colt's Magazine Rifle Opened.

# CHAPTER VIII.

## AMMUNITION FOR SPORTING RIFLES.

### GENERAL REMARKS.

IN commencing the task of investigating the ammunition suitable to, and used for, sporting purposes, I shall not enter into a description of any of the numerous varieties which owe their existence to caprice, or something worse, rather than to their practical value to the sportsman, but shall devote my space to a full consideration of those standard types of cartridges which are of approved and generally acknowledged excellence, with a view of placing before my readers as complete an amount of practical information on the subject as I have been able to accumulate.

The main features to be considered in sporting, as in all breech-loading rifle cartridges, are, (1) the case or shell containing the charge; (2) the cap or primer for its ignition; and (3) the powder, which, in these chapters, will be taken as Curtis and Harvey's No. 6 treble strong, unless otherwise stated—this brand of powder having, from its great uniformity and other qualities, been adopted as the standard powder for rifle work for a number of years; (4) the wad or wads, for confining, as far as is practicable, the powder gas behind the bullet, and also for sweeping and lubricating, if possible, the barrel with each successive discharge; and, lastly, the bullet or projectile, made of lead, more or less hardened with tin or other alloy. This in general is of conical form, and more or less hollow, or otherwise constructed so as to expand on striking, and thus inflict as severe a wound as possible in proportion to the calibre of the weapon used. As a rule, these bullets are wrapped in a jacket of fine tough paper, for the purpose of diminishing, in great measure, the actual contact of the lead with the interior of the barrel in the act of firing, though a naked and unpatched bullet is sometimes used and recommended by some rifle makers. I confess my inability to discover any material advantage likely to accrue from the use of the naked projectile; on the contrary, however it may be grooved or "cannelured," and coated with lubricating compounds, there is always the danger present, that when the rifle, from neglect or ill usage, gets roughened or rust-pitted inside the bore, this bullet, in rushing over such rough places, is much more likely to suffer abrasion, with its attendant "leading,"—impairing, if not destroying the accuracy of the arm until the defect is corrected in the workshop. Other minor, but still objectionable, features in unpatched bullets are, the facility with which the coating of lubrication picks up and retains particles of sand and grit, so universally diffused at times in the dust-laden atmosphere of India and similar climates; and the effect produced on the interior of a fine rifle by the use of such scouring material can be easily understood. Again, it must be remembered that the continued contact of grease or fat with the lead soon causes the formation of a crust of oxide on the surface of the metal, and (in bad cases) renders the projectile nearly if not quite useless. This effect is produced, according to Sir F. Abel, in a "very short time, even when the lubricating material was composed of one part of tallow only to five parts of beeswax." On the other hand, the only objections to the paper wrapping is that it is affected by damp, and that the art of patching bullets—when these have to be made up by the sportsman away from a supply of machine-made ones—requires a little attention, and causes some little trouble. As to the first objection, I can only remark that the same attention bestowed on keeping one's "powder dry" will be more than sufficient for paper-covered bullets; and, as to the patching, ten minutes devoted to the details of the process will enable anyone to master it. With respect to the comparative working of the two kinds of bullets during firing, there is no doubt that, when everything is in good condition, and at short ranges, the unpatched bullet works well, but certainly not better than the patched one; while at long ranges we yet await the introduction of the former.

## CARTRIDGE CASES.

I shall avail myself of the ready and popular existing method for dividing sporting rifle cartridges into three classes, easily distinguished from each other by the differing external appearance of the case or shell holding the charge. The first division is that in which the *coiled* brass Eley-Boxer expanding shell is used. This plan is most generally used for the leading Express calibres, such as ·360, ·400, ·450, ·500, and ·577—especially the three latter sizes; and also for the well-known long or mid-range Government patterns, ·450 or "Martini-Henry," and the ·577 or "Snider" cartridges. The next division includes *solid-drawn* metal shells, of which there are a great variety, including those suitable for the calibres above mentioned, also the small sized so-called rook rifle cartridges ·380, ·360, ·295, and ·220, &c. The third division is entirely confined to the larger bores, the shells being of pasteboard, similar to, and in many instances identical with, the well-known shot cartridges for 12 and other bores; in the larger sizes (8 and 4 bores) the case is made proportionately stronger.

The Eley-Boxer cartridge (so called after its joint-inventors) claims our first attention. This mode of construction was first devised to meet the requirements of the Government for a breechloading cartridge to suit the then (about 1865) newly-adopted Snider breech action for military purposes. It was designed to suit an arm with somewhat feeble power of extracting the fired shell; and one of the chief points was to render that process an easy one. No doubt it has answered admirably when kept to its original purpose—that is, employed in a fairly large calibre, with moderate powder charge, and an expanding bullet *requiring no wad* or auxiliary gas check. The wide experience gained during our long use of the Snider rifle has, no doubt, satisfied everyone that this type of shell, when so used, works well. Following the lead of the authorities, rifle-makers began to apply this style of cartridge to other conditions, that is, to small calibres, high powder charges, and bullets quite destitute of the expanding property of the Snider compound projectile—in fact, bullets more or less solid, and *requiring a wad* or auxiliary gas-check. Sporting cartridges of this character, made up suitable for the Express rifle, have been largely used; and even now some rifle-makers continue to turn out weapons regulated for this ammunition. There is some excuse for the continued use of the Boxer shell in those cases where only a moderate amount of accuracy and power is required; but its prominent defect will always debar its use where the highest degree of excellence is insisted upon. The walls of the shell, only some ·004in. in thickness, and its formation into a cylinder only by the strip of metal being rolled on a peg or mandril, effectually prevent the use of a proper well-fitting wad or gas-check of such large diameter, as compared with the bore of rifle, as has been proved beyond dispute to be requisite before the wad can perform its work properly. The mode of securing the bullet in these shells is open to grave objection—it being either "crimped," when the shell is forced into a groove or cannelure extending round the bullet near the base, or two indentations are pinched into the bullet when in place through opposite sides of the shell.

In either case it is but partly secured, and, in consequence, the cartridge suffers in both accuracy and portability. This inability to take a proper-sized wad is the great failing of the coiled shell; the minor ones being its inferior capacity, length for length, when compared with the solid-drawn shell, and its composite structure—one part being attached, more or less soundly, to the others, with the liability to disruption under those exceptional strains and conditions generally occurring, in sporting experiences, at the wrong time. That this plan affords a fairly cheap and moderately effective class of sporting ammunition, I do not deny. The case is easily extracted after firing, but is not very well adapted for re-loading; and it gives, no doubt, every satisfaction to that class of sportsmen who are content with little trouble and moderate results.

The group opposite illustrates the Eley-Boxer ·500 Express cartridge, Fig. 50 being an external view, Fig. 51 a vertical section of the same, and Figs. 52, 53, and 54 similar sections of the lower part of the shell in the "making up" stage of manufacture—showing the principal components of the plan and the manner in which they are built up. The case consists of a piece of sheet brass, cut into the proper shape, and from ·004 to ·005 in thickness. This is wrapped round a "former," having been previously coated on the inside with lacquered paper to assist in keeping the shell waterproof and prevent deterioration of the powder. The end of the coil so obtained is then turned in, and, together with the "paper pellet" and "base cup" and iron "base disk" (which latter has previously had a "cap chamber" inserted therein), are assembled as in Fig. 52, (the base cup being inserted in a mould to prevent bursting under pressure). The pellet is then forced down (as in Fig. 53) by a suitably-formed punch applied inside the shell, the effect being to bind the whole together. Fig. 54 shows the final stages of this process, only here another punch has swelled out the head of the cap chamber into a bulb, firmly riveting it at the same time to the base disk by the countersink in it. The "flash hole" is now pierced in the dome of the cap chamber, and the shell is complete and ready for the reception of the primer and anvil, which are shown in position in Fig. 51.

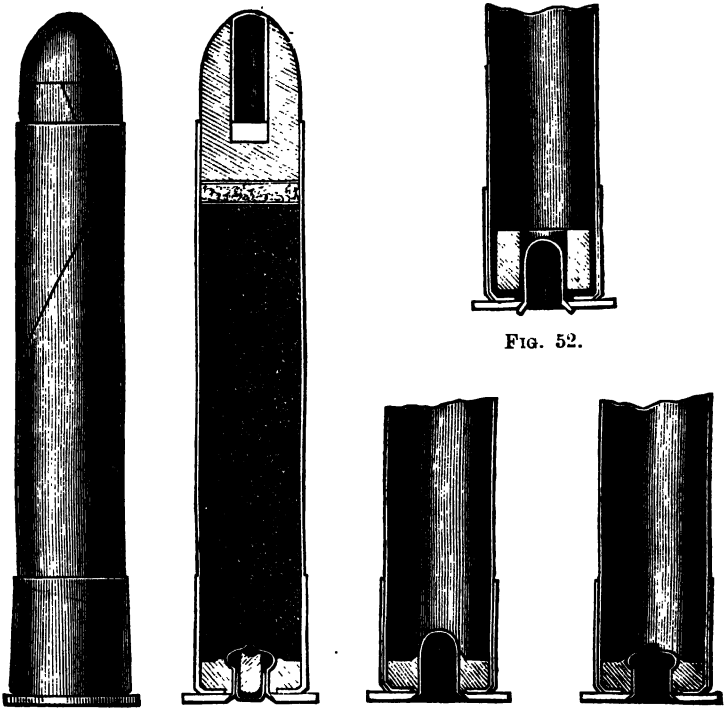


Fig. 52.

Fig. 50. Fig. 51. Fig. 53. Fig. 54.

Express Eley-Boxer Cartridge.

The charge of 120grs. powder is poured into the shell, and a thin (·025in. thick) jute wad laid upon it, then a hard felt wad (·090 thick, ·520 diameter), another jute wad, then the bullet, 340grs. in weight and ·500in. in major diameter, wrapped, nearly three-fourths of its height from base, with a paper patch going twice round, making it ·508 over all. When the bullet is placed in position, the shell is pierced, and so driven inwards on each side of it as to secure the bullet from falling out when the cartridge is ready for use. The bullet is machine-made—that is, "swedged" in tools under considerable pressure; it has a flat base and a hollow or cavity from the point downwards for more than half its length, having a copper tube inserted to preserve the symmetry of the point and also the accuracy of flight, which would be somewhat impaired if the hole in front were left unstopped. On glancing at the section of this bullet shown in Fig. 51, it will be seen that it is not well proportioned for accurate flight, being short in comparison with its diameter, and obviously with its centre of gravity much behind its centre of figure—faults calculated to develope errors in flight, increasing in intensity as the range fired at increases in distance; therefore we must not expect much accuracy from this bullet except at the short and medium sporting ranges.

As to the point involved in the relative diameter of the wad with the work it is supposed to do, it will be found on examination that the "chamber," or recess cut in the breech end of the barrel to receive this cartridge, cannot be less in diameter than ·535 across the base of the bullet, on account of the overlap in the wall of the shell. Thus, when the shell is expanded to fit the chamber in firing, its inner diameter cannot be less than ·520, allowing ·005 for thickness of shell on one side, and ·010 on the other on account of overlap; but, we have before found that the wad is only ·520 diameter. Then where is the gas check?

That the wad may, or may not increase in diameter to a certain extent under the pressure of the gas is a question that does not apply specially in this case, more than under like conditions in the solid drawn shell; therefore it can be left out of the question.

I have selected the ·500 cartridge to illustrate these points in the Eley-Boxer system as applied to Express ammunition, but the other calibres are affected by the same faults, rendering it unnecessary to further consider the coiled case as applied to sporting purposes.

## SOLID DRAWN SHELLS.

Our second division of sporting ammunition is that in which the shell or case is formed of one entire solid piece of tough hard metal, an alloy of copper, &c.; in fact a brass, that should be specially constituted with a view to the manufacturing processes it has to undergo, and its ultimate work as a cartridge case. It must be sufficiently strong to be capable of resisting severe strains, at the same time it must have the requisite flexibility to admit of re-sizeing or reducing to its original dimensions after firing. This *solid drawn* shell, as it is called, to distinguish it from the coiled one just described, made its first appearance in this country some eighteen years ago from the United States; then, however, in only a partly developed form—that is, instead of the solid head of thick metal from which the thinner walls of the shell are elaborated by an exceedingly ingenious series of operations presently to be described, the head was then formed of metal uniform in thickness with the rest of the shell, the rim being folded or raised over, and having a cavity between its folds used to hold the fulminate acting as the means of ignition in the once popular "rim-fire" cartridges. With anything like a modern rifle charge these shells were very unsafe, and even with light charges, unless made of the best metal, they were apt to burst at the rim. They were also objectionable as they did not admit of re-priming for use after the first firing.

Shells of this design, but with "central fire" primers, were soon introduced, strengthened internally with a "base cup;" but it was found that nothing would stand the heavy strain upon a rifle cartridge, loaded to suit the requirements of modern sport, but the solid drawn shell, which, since its introduction, has become the only resource of the rifle-maker when the best results are to be obtained.

Before we go into the manufacturing details connected with the production of these shells, it will be well to examine a few of the special points involved in their use, their varieties, and their respective values from a sporting point of view.

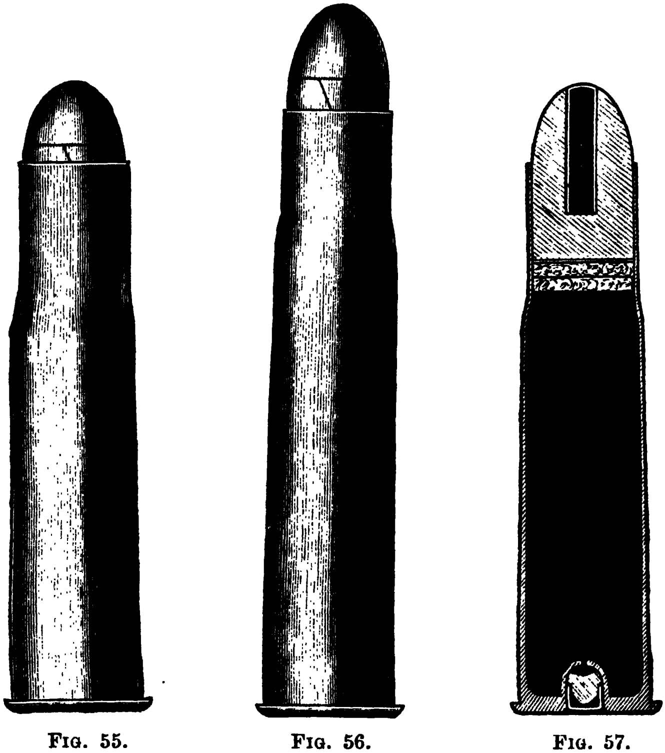


Fig. 55. Fig. 56. Fig. 57.

Express Solid Drawn Bottled Cartridges.

There are two kinds, of very different shape, one known as the "bottled" and the other, the so-called "straight" or "taper" shell, this latter having a slight and uniform taper for its entire length from the head upwards; the "bottled" shell being tapered to a similar extent only to a point towards its mouth where it is suddenly reduced in diameter, or "necked" to an almost parallel tube, more nearly approaching the calibre of the barrel it is used in than the body part of the shell. This form, as of somewhat earlier introduction, we will take first.

The annexed figures illustrate two specimens of bottle-necked cartridges, Figs. 55 and 57 being the ordinary ·500 Express, containing a charge of 130 grains powder, and similar wads and bullet to those employed in the cartridges shown in Fig. 51, except that in this case the superior rigidity of the shell permits the use of a large and well-fitting felt wad. It will be seen at once that in a shell of this model the quantity of powder used must come up to, or properly be rather above, the shoulder. If this is not the case, the wad is apt to drop below the neck into the wide portion of the shell, and thereby impair, if not utterly destroy, one of its most important functions, that of retaining the powder gas behind it, and thus preventing it from rushing past the bullet. Consequently in these shells one regular charge must be used, as there is no ready means of reducing the capacity of the shell at the wish of the user. Fig. 56 shows what is called the "Magnum" ·500 Express cartridge, holding about 30 grains more powder than the ordinary pattern, and designed to satisfy the wants of sportsmen who, having to encounter actively dangerous game, require strong smashing power, even at the cost of some deterioration in accuracy. But this latter defect is not perhaps of much importance at the short ranges within which it is considered judicious to fire at the more dangerous animals.

Reverting to the question of using other than the regular charge in a bottled cartridge, though not advisable from one point of view with a double rifle for reasons explained in the next chapter, circumstances will arise where a reduction of the powder charge may appear beneficial. The existence of this want, together with the opportunity afforded of being able to

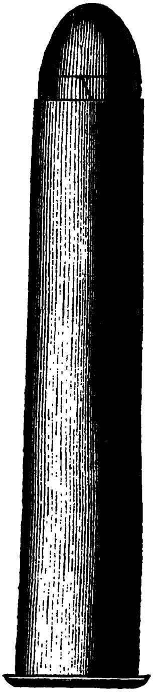


Fig. 58.

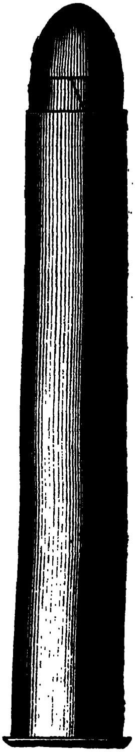


Fig. 59.

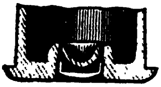


Fig. 61.

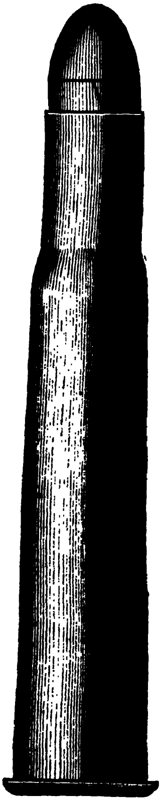


Fig. 60.

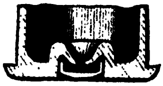


Fig. 62.

use solid drawn shells in rifles chambered for the Eley-Boxer case, has led to the production of the taper solid drawn shell, illustrated in Fig. 58. This represents a ·500 Express cartridge of this kind; Fig. 59 showing a similar taper solid drawn shell made to agree with the ·450 Express Eley-Boxer cartridges, Fig. 60 showing the ·450 Magnum Express cartridge. The ·500 solid drawn cartridge is identical in length and external diameter with the Eley-Boxer ·500 shown in Fig. 50, but in consequence of none of its internal capacity being taken up by the paper pellet of the latter, there is no difficulty in getting in at least ten grains more powder, leaving ample room for proper wads and a secure bullet hold.

At this point, where we have arrived at the consideration of *two* cartridges that are interchangeable to a degree in the same rifle, it will be proper to remark that the sportsman must only expect to be able to utilise this dual arrangement to a limited extent. It will be fully explained in the next chapter that no material change in ammunition can be expected to give good results (in a double rifle especially) if the arm has been originally regulated in a proper manner for its normal charge. The general construction of this taper shell differs in no material feature from that of the bottled one previously described. In fact, all solid drawn shells are made on the same general principles; and, where any variation is apparent, it will be found in the arrangement of the "cap" or "primer," and its "anvil," or such construction as is equivalent to the latter.

Figs. 61 and 62 show an arrangement of primer without a separate anvil, in which a little elevation or dome will be seen to be raised within the cap chamber, against which the inside or primed portion of the cap is forced by the blow of the striker to cause ignition. The flash is conducted to the charge either by two holes (Fig. 61), one on each side the dome, or by a single one through its apex (Fig. 62). This construction is not generally approved, as the dome is apt to get beaten down from the blow of the striker when the shell is used a second time, while the flash-holes at the sides, having to be used when extracting the fired cap, are inconveniently situated for that purpose. In the ordinary arrangement, shown in Fig. 57, on page 298, the fired cap containing its anvil is easily thrust out by means of a wire peg suitably mounted and passed through the central flash-hole in the cap chamber.

Before passing on to the smaller kinds of solid drawn cartridges, it will be well to notice a few imperfections existing in the shells for full Express charges that we have already examined. It will be seen from the illustrations that in neither the taper nor bottled kind is the *neck* of the shell long enough to properly cover the papered portion of the bullet, when sufficient room has been left for an effective wad. This I consider to be a mistake, as a longer neck would not increase the total length of the loaded cartridge in the least, but the security of the bullet in the shell, and its consequent superior endurance of rough usage, would be much enhanced if the shells were another quarter of an inch or so longer in this part. I think also that the taper shell would be much better if slightly necked or made nearly parallel to some little distance *below* the situation of the wad—thus insuring the fit of the latter—and not, as at present, impairing that fit by the gradual widening of the interior of the shell from the mouth downwards. There can be no doubt that the bottled shells would decidedly be the better for both necking a little lower as well as increasing the length of neck. This would allow a charge of powder below the maximum capacity of the shell to be used, without destroying the arrangement by which the fit of the wad is secured.

We will now turn our attention to the smaller descriptions of solid drawn cartridges. Fig. 63 shows the ·400 bottled

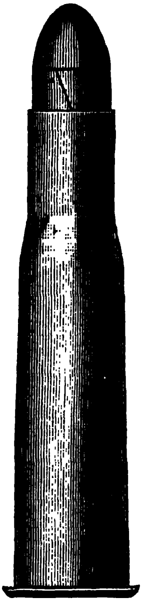


*Fig. 63.*
*·400 express*

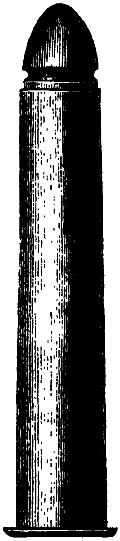


*Fig. 64.*
*·360 express.*

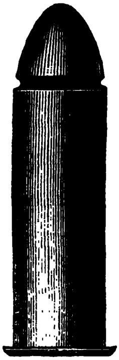


*Fig. 65.*
*·425.*

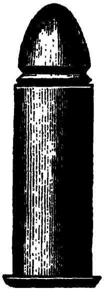


*Fig. 66.*
*·360 No. 5 rook.*

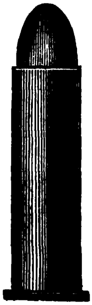


*Fig. 67.*
*·295 or ·300 rook.*

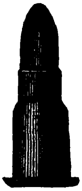


*Fig. 68.*
*“Morris” ·230.*

*Fig. 69.*
*Winchester ·220.*

Express, and Fig. 64 is the ·360 taper so-called Express. Neither of these require any special comment, except that they mark the transition between the Express cartridges proper and the smaller and much less powerful kinds, some of which are known as "rook" and "rabbit" rifle cartridges. The larger of these, known as ·442, ·430, ·425, and other similar sizes, suitable to the calibres expressed by these figures, are much used abroad for such game as small antelope, bustard, &c., and in the Australian Colonies for kangaroo, &c., being employed with rifles light, handy, and fairly accurate, and sufficiently powerful for such game as are above enumerated. The still smaller sizes, ·380, ·360 No. 5, and ·300 or ·295, are chiefly used at home for rook, rabbit, and seafowl shooting. Of these, for some years the ·380 calibre was the popular one; and a cartridge of what was then considered fair excellence was generally in use. Though considerable accuracy could be obtained with this cartridge, still, for shooting in an inclosed country it was found to be objectionable on the score of its wide range, exception also being taken to the mangling of the game in consequence of its comparatively large calibre and the hollow pointed bullet latterly used, especially in the ·360 No. 5, a cartridge interchangeable with the old ·380, and in most points a decided improvement upon it.

The most satisfactory rook cartridge yet introduced is no doubt the ·300 or ·295 calibre, shown in Fig. 67. This is a solid drawn shell loaded with 10grs. powder, a wad, and a solid cannelured bullet of 80grs., unpapered, as all these small rifle bullets are; the low pressures of the small powder charges rendering the use of naked bullets less risky than is the case with the full charges of the actual Express rifles.

The illustrations represent the more modern and accurately shooting cartridges of this particular kind—Fig. 65

showing a view of the ·425 calibre, 30grs. powder and 230grs. cannelured bullet with felt wad between. This cartridge, though, of course, having a high trajectory, shoots with considerable accuracy up to quite 300 yards under fairly favourable conditions. Fig. 66 is a similar view of the ·360 "No. 5" cartridge, containing 15grs. powder, a wad, and bullet weighing 135grs., and of precisely similar construction to those in the previous figures. With this cartridge good shooting has been made up to and including 100 yards. In 1878 the second prize of 5*l.* was taken with a double rifle firing this cartridge in the "Martin-Smith" competition at Wimbledon N.R.A. Meeting, distance 110 yards, no rest.

Fig. 67 shows the ·300 or ·295 cartridge, that is rapidly superseding the former for reasons I have given above. In the competition above mentioned, at the N.R.A. meeting in 1883, a double rifle firing this cartridge took the second prize of 5*l.*, the distance and conditions remaining the same.

Fig. 68 shows the cartridge designed for the "Morris tube," now so much used throughout the army as an auxiliary in musketry instruction. A number of rook rifles are being manufactured to suit this ammunition, which suits the ·230 calibre, and has a charge of 4grs. fine powder, two wads, and 40grs. bullet.

In the course of some trials of the above tubes firing this cartridge, lately made at the R. S. A. Factory, Enfield, I am informed that, with the tube inserted in a regulation Martini-Henry rifle, good practice was made from the 500 yards range (on a calm day), groups of ten shots in nearly two feet square not being uncommon. The angle of elevation, of course, was high; about equal to the 1150 yards elevation of the service cartridge.

There is still another of these tiny cartridges I must notice, a rim-fire one of American manufacture, the Winchester Company's ·220 calibre, shown in Fig. 69. This is loaded with not more than 4grs. fine powder and a bullet only 30grs. with no wad, yet, at ranges from 10 to 40 yards, it is most accurate.

The only remaining solid drawn shell cartridge to be noticed is the one generally used in the "Mid-range" rifles constructed to suit the conditions of sport in South Africa, or "Cape rifles," so-called. As this type of ammunition in all essential features resembles the familiar "long-range" M. B. L. cartridges, fully treated in the section of this volume upon Match Rifles, I may refer my readers to that portion of the work for information upon this particular class of rifle ammunition.

The last division of sporting cartridges to be considered is that kind in which the shell or case holding the charge is the well-known pasteboard one, so long used in B. L. shot-guns. In some varieties, especially for the larger sizes, these are strengthened towards the base by a coil of sheet brass, and, indeed, for some time the now familiar "Perfects," constructed entirely of thin metal, have been to some extent used for this kind of ammunition. It is not necessary to give illustrations of such well-known articles; and a few words on the method of loading will suffice. For 12-bores the powder load varies from 4 to 7 drams, according to weight of rifle and kind of game sought; as a rule, spherical bullets are used, whose mode of treatment will be found further on. The usual practice is to put an ordinary thick felt wad on the powder, and then the bullet, either enveloped in a greased linen patch, or naked; in the latter case a little melted lubricating material is poured upon its upper surface when in the shell. Several contrivances in the shape of perforated wads, &c., have been devised for seating the ball and so improving the shooting obtained, but I have no reason to believe that any of them are of great practical value, or much improve on the ordinary plan, provided in the latter case care be taken to seat the ball *with the "get" upon the wad.* There is no material difference in treating the larger bores, excepting, of course, the increase in powder load and bullet weight, the former sometimes reaching the enormous amount of as much as 14 drams in the 4-bores—necessitating most ponderous weapons to enable any human shoulder to bear the recoil.

### RIFLE GUNPOWDER.

In considering gunpowder, especially in relation to its use in rifles, I must add a little to my remarks on this subject in Vol. I., pp. 293, *et seq.* I may clear the ground by at once stating that up to this present date no explosive yet devised can equal black gunpowder for rifle purposes.

That wood or E.C. powder, or similar compounds, *may* be so perfected as to come up to the required standard is quite probable, but at present it remains to be done; this is the more extraordinary, as the necessity for avoiding deposit in the barrel during firing is of much more vital importance in a rifle than in a shot gun, and this feature is an admitted excellence in these compounds. In addition to which, both Schultze and E.C. powder with similar charges produce a higher muzzle velocity and much less recoil.

For rifle use the powder must be made of the best and purest ingredients, the nitre free from other salts, the sulphur free from acid, and the charcoal properly prepared from suitable wood, and containing the smallest possible proportion of earthy substances; otherwise, the great desideratum of the rifle shot, a "clean" burning powder, will not be produced.

These components, mixed in proportions ascertained by long and careful experiment, are then subjected to the most thorough and complete manipulation, as described in Vol. I. After the "cake" is formed, it is broken up or "granulated,"—a most important feature in the powder-manufacturing process, as upon the size and uniformity of the grains largely depends the rate of combustion of the charge. This regularity of grain is provided for by the "sifting" process, in which the granulated powder is passed through sieves of wire, each with a certain number of meshes to the linear inch, but is retained upon others as much finer in the mesh as may be determined. It is obvious that the greater disparity there is in the meshing of the two sets of sieves the more irregular the powder will be in grain. The Government powder for small arms is allowed to pass through meshes of 12 to the inch linear, and is retained upon those of 20 to the inch; thus there is a marked degree of difference in the grains of this powder, and we should be justified in assuming that the rate of combustion varies in different charges, as they consist of a higher or lower percentage of either the larger or the smaller grains. No doubt sifting or "gauging" to a high standard of uniformity adds to the cost of production; but it is the foundation of every excellence in rifle shooting—that is, every other good feature in the weapon and its ammunition is vitiated by the use of powder irregular in its combustion.

Another process adds to the durability of the powder, and also gives an increased power to resist the effects of damp, that is the "glazing," in which the grains are polished by friction against each other, a quantity of powder being rotated for some time in a reel or cylinder. This polish should be the legitimate effect of friction, and not unduly accelerated or artificially produced by the introduction of black lead or plumbago during the process, as the presence of this latter substance only tends to increase the solid residue or fouling left in the rifle after firing.

The tests to which powder may be subjected by the rifleman are but few in number, and those are mostly of a tentative character. When satisfied by inspection and comparison that the granulation is all right, a good rough-and-ready test for density is the space taken up, say, in a cartridge shell by a given quantity by weight, when, if the powder be of less density than usual, it will occupy more space; if of greater density, less space. The flashing by ignition of twenty grains or so on a piece of clean white paper will give an indication of the cleanliness or otherwise of its burning, and will also show if the powder be affected by damp. But *the* test of all is the firing of a series of shots at 1000 yards with a known good long-range rifle, using bullets that can be relied upon—when the qualities of the powder, whether good or bad, will soon appear.

For ordinary sporting purposes, as long as the powder burns clean, and does not deposit so much fouling as to interfere with the accuracy of the arm, an extreme degree of excellence in other respects may be dispensed with; since a difference in muzzle speed which will greatly interfere with long-range shooting has no appreciable effect on accuracy of diagram at such short ranges as 100 yards. It has long been well known that damp exercises a most injurious effect upon powder; but it is not as generally known that crushing or bruising the powder, as in the act of loading, is almost equally injurious. There is little choice between using powder moderately damp on the one hand, and crushed and pounded into dirt on the other.

The manufacture of gunpowder being a combined mechanical and chemical process, it will be easily understood that it cannot be successfully carried on without considerable experience and care; and the high character of the best English rifle powder is sufficient evidence of the ability of our manufacturers.

As an illustration of the fine work a first-class powder is capable of producing, I give the following statement, made to me by the well-known rifle maker and shot, Mr. F.

Osborne, of Birmingham: Early in 1880 he was engaged in testing the muzzle speed of an M. B. L. rifle with a Le Boulengé chronograph; the cartridges were loaded with 80grs. Curtis and Harvey's No. 6 powder and a 540gr. bullet; the firing was continuous, the barrel not being wiped out between shots. After a blow-off shot being fired, the following speeds were obtained in feet per second:—

1300
1297 Av. 1297·8, being only a difference of 4 feet per second
1298 obs. vel. between the highest and lowest speeds
1298 at 105 ft. obtained in the five consecutive shots.
1296

I can imagine nothing more satisfactorily conclusive than this in showing how well deserved is the high position universally conceded to the rifle powder manufactured by this well-known firm, whose No. 6, as was stated in the opening of this chapter, is the generally accepted standard of excellence in rifle gunpowder.

## Waddings.

Considering its important bearings on results, there have been few subjects so neglected as the matter of wad or gas-check in breechloading rifle ammunition. In other mechanical arrangements, where air, gas, steam, or water is to be prevented passing a piston working within a cylinder and subject to great pressure, considerable attention has been paid to the details involved in the success of contrivances for effecting the desired purpose. But when the piston is an inelastic leaden plug, driven up a grooved cylindrical tube by the enormous force of hot powder-gas, the same precautions do not seem to have been thought necessary. In the high-class muzzle-loading rifle, now obsolete, this detail forced itself early into prominence, mainly on account of the beneficial effects found to accrue from the "sweep" or cleaning-out action in the process of loading of a good well-fitting wad of diameter superior to the calibre. As already explained in treating upon cartridge shells, it is only the latter development of the solid drawn shell that has enabled us to avail ourselves of similarly well-fitting wads in the breechloading rifle.

The work of the wad may be taken as three-fold; first, to seal the joint in rear of the bullet and form a perfect gas-check; secondly, to wipe or sweep out the barrel; thirdly, to impart as much lubrication as possible to the interior of the bore, so as to facilitate the passage of the next bullet, and reduce the adhesion of the solid residue of the powder-charge or fouling that remains after such successive discharge. Some kinds of wad perform one or more of these duties better than others. A firm, tough felt wad, well saturated with a lubricating compound, but not unduly softened, is probably the best all-round material for rifle wadding, especially when used with a moderate powder-charge and a heavy projectile. With these conditions reversed, a wad of softer material works well, and, in spite of losing the sweeping action of the harder wad, one of a rather soft, greasy compound is found to be fairly efficient for short-range work. This kind of wad is easily made by the sportsman, and does its work apparently by sealing the joint under the pressure of the gas, and by being crushed up during its passage along the barrel. In this way it amply lubricates its interior, and so prepares it for the reception of the solid fouling which, being deposited upon such a surface, is less adherent than when plastered upon a dry, hot barrel by the blast of the explosion, and consequently is much more easily removed by the next bullet that passes up the bore. This wad is more especially useful with heavy powder-charges in small calibres, and is well suited to light and fragile shells.

When felt wads are used, they should be at least ·025 or ·030 *larger* than the calibre, and can easily be forced into the shell by proper tools and a little pressure, care being taken that the thrust be checked just as the wad arrives upon the powder. It is customary to use two felt wads each about ·09 in thickness, in preference to one thicker, partly because they are more easily inserted into the shell. It is also advantageous to have a thin jute or card wad barely the internal size of the shell between the wad proper and the base of the bullet; and when the soft wad above mentioned is used, a jute wad should also be first placed upon the powder.

The military authorities having sanctioned the use of a thick, hard, beeswax wad in the service Martini-Henry cartridge, found themselves compelled to hollow or cup out the wad so as to facilitate the crushing up of the same by the powder blow, otherwise, more particularly in cold weather, the wad was blown out of the rifle a solid unyielding mass that had done little or no duty whatever; this rather tends to show that a softer wad of a similar kind would be more generally effective under various temperatures, either by itself or as an auxiliary to the felt wads.

These soft wads are very easily made. All that is wanted is a plate with a number of holes therein the size of the wad required (which should be the full internal diameter of shell and no more). This plate, being the desired thickness of the wad, is laid on a flat surface, and the melted fat or composition poured all over it; then, when cool and set firm, the superfluous material is scraped from the upper surface of the plate, and the wads pushed from the holes, when they are ready for use.

When the sportsman has to cut his own felt wads, care should be taken that a keen, sharp tool is used for this purpose, as wads cut with a blunt cutter have a bruised and unsound edge, and are therefore much less efficient than they would be if properly cut.

As to the matter of the lubricating material to be used either for saturating the felt wads, or constituting the soft wads, or coating the bullets that are used without paper jackets, there can be no doubt that the question of climate and temperature must enter into the consideration. For instance, the best lubrication for use in the Indian hot season would most probably fall off in efficiency if used in a Canadian winter; thus the question is not an easy one to settle in a hard and fast manner. I can only indicate the lines upon which good results are generally obtained. A mixture of beeswax and tallow or vaseline should, for use in a cool climate, have the softer element predominant, while for a hot climate the reverse should be the case.

## BULLETS.

As the kinds of game sought by the rifle-shot offer great variety, including all sizes, from the elephant to the squirrel, we must expect to find a corresponding variation in the projectiles used in sporting rifle shooting, from the quarter-pound leaden sphere of the 4-bore to the tiny missile of the ·220 rook rifle—exhibiting such differences as to be rather embarrassing at first consideration.

Setting aside explosive shells as both dangerous and unsatisfactory—and very properly themselves exploded in the opinions of modern rifle users—we can at once divide sporting rifle projectiles into two main classes, solid and hollow; the latter name being applied to bullets having a cavity of any kind, frequently filled up by a copper tube or otherwise. We can also consider them as either spherical or conical in form, either mode of division equally suiting our purpose.

Spherical projectiles, or bullets proper, are now chiefly used in the larger calibres, such as 12, 10, 8, and 4 bores, and are invariably cast in moulds by a process well known to every sportsman, though it can be easily spoiled in spite of its apparent simplicity. The lead or alloy should be melted in a large ladle (a small one being used for pouring), and kept sufficiently hot to be perfectly fluid, not by any means allowed to either become too cool to run freely, or to get red hot and so waste. The mould being well warmed and quite dry (or an explosion may result on the introduction of the molten metal), it should be covered inside with a coating of soot from the smoke of a tallow candle or resinous torch. The molten metal should then be taken up with a small ladle having a clean well-cut lip for pouring it out; and a steady uniform stream should be poured into the mould, not in such quantity as to choke up the "get," or in so fine a one as to cool as it goes in; neither on any account should the pouring be intermittent, as any of these defects in manipulation will result in imperfect castings. Should the metal be impure and throw up a quantity of slag, a little tallow or resin thrown upon its surface will assist in clearing it. If an alloy is used, each time the pouring ladle is dipped in for a cast the mixture should be stirred, as the alloys used for bullets are mere mechanical mixtures, and if left unstirred the lighter and harder metal separates itself from the other in great measure; consequently, if not stirred occasionally, some bullets may be harder than others, and so affect the accuracy of fire.

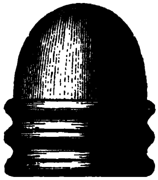
Spherical bullets, cast in a properly constructed mould, admit of no improvement after casting, except, of course, the removal of the "get;" but conical ones, if not grooved or "cannelured" (for the reception of lubricating material), may be "swedged" or driven into a suitably constructed die by blows upon a punch applied to the base of the bullet, which is then ejected from the die much improved in uniformity of shape, size, and density, being a near approach to the machine-made bullet in all essential features. These bullets, after the removal of any superfluous fringe of metal left by the latter process, are then ready to be "patched" or provided with their paper jackets. This is usually done by a piece of paper of suitable texture, cut to the proper size and shape, being wrapped round a taper peg; the paper should go twice round and be fixed by a touch of gum—the less the better; when drawn off the peg, the paper tube thus formed should, when dry, be drawn upon the bullet, the point of the latter entering the wider end of the tube. When this is drawn on so as to cover the cylindrical part of the bullet, leaving the point exposed, it will fit closely and tightly, if the peg upon which it was formed was of the proper size. The portion of the paper extending below the base of the bullet should be neatly twisted, and the superfluous portion, if any, cut off. The bullet is then ready for use, provided that, in hollow-fronted Express bullets, the tube has been driven into the cavity before patching, which can be conveniently done during the swedging process.

There is a detail connected with the patching process that must not be overlooked, that is, the paper must be so wrapped that the edges form a "left-handed" spiral when on the bullet, as shown in the figures of loaded cartridges. If wrapped the other way, for use in the ordinary "right-handed" spiral grooved rifles, the shooting will be impaired.

The machine-made bullets are compressed in powerful machines, generally from metal formed in coils like wire, by hydraulic pressure employed in forcing the semi-fluid mass through a die of the required size. The patching is done also by a machine process, and without gumming the paper jacket. Whenever practicable, the sportsman will, of course, prefer to use the finished machine-made bullets, which are no doubt as generally procurable now all over the world as powder and lead; but at the same time it is well he should be able to provide himself. In addition, therefore, to the mould for papered bullets, one may be useful that will enable cannelured bullets to be cast, thus rendering him independent of the patching process, as they only have to be dipped in melted lubricating material to prepare them for use. It will be found advisable to make these cannelured bullets of a little harder alloy than the patched ones, in order to reduce the risk of "leading" the barrel and somewhat reducing the extra friction caused by the superior diameter of this bullet over that of the papered one used in the same shell. The shooting is not materially impaired by this bullet being used, provided the mould be correctly proportioned to suit the rifle.

The faults most likely to occur in bullets so as to impair their successful use by the sportsman are numerous, but I may call attention to the most obvious and important ones, viz., (1) Those arising from defective material; that is to say, bullets either too hard or too soft, the former in extreme cases failing to properly take the grooves of the rifle, and consequently shooting wildly, and, if Express pattern bullets, not expanding properly on striking the game. If too soft, undue distortion takes place from the powder blow, and thereupon excessive friction, liability to "lead," and defective flight owing to the damaged figure. Alloys, whose degree of hardness equals from *five per cent.* of tin with lead for the softest bullets, and about *ten per cent.* as the hardest, are the best mixtures for general purposes. (2) Arising from defective shape. A grave fault in a conical bullet is that when the base of the same is "unsquare," or not at right angles to the axis, it is next to impossible to obtain good shooting with bullets possessing

Fig. 70.



12 bore
solid bullet.

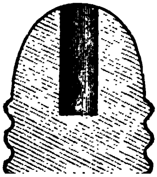


Fig. 71.

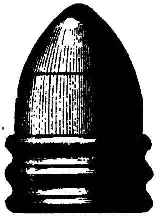
12 bore hollow
pointed bullet.

LARGE BORE CONICAL BULLETS.

this defect in a marked degree. Also, if bullets are incorrect in size, and of greatly varying weight, or with the cavity in the fore part much to one side, or badly patched with unsuitable paper, no one can expect good results with such improperly made articles.

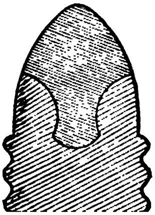
Among the varieties of sporting projectiles calling more particularly for notice, other than the specimens of Express bullets illustrated in the drawings of those cartridges, are some examples of conical bullets as used in the larger bores; sometimes these are hollow pointed, but more frequently solid. I give sketches of both kinds suitable for a 12-bore rifle, the larger sizes being designed on very similar lines. Fig. 70 represents the former, Fig. 71 the latter.

Fig. 72.



12 bore bullet, with steel point.

Fig. 73.



section of same showing point.

Steel-pointed Bullets.

These bullets are of dubious value, as though they exceed the sphere in weight they much increase recoil, and really require a quicker pitch of rifling; thus their speed is less than that of the sphere, other things being equal. The solid ball is sometimes made with a steel point which is placed in the mould and the metal poured in, forming a compound bullet, liked by some sportsmen under the belief that the penetration is largely improved; but this is questionable, the tendency of the lead being to "overtake" the point on impact. It is therefore most probable that a hard solid ball would be more effective. I give a sketch of such a bullet in section, showing the point *in situ.* It will be well to call attention to the fact that, unless carefully manipulated, this point is apt to get on one side during the casting process; and, should such bullets be used, there is a risk of the side of the point scoring up the interior of the barrel, and so seriously injuring it.

It will be seen that the bullets just described are cannelured for use with external lubrication, the conditions existing in rifle barrels of large calibre permitting this, as the fouling is much less unmanageable than in the smaller calibres when the latter are used with large charges.

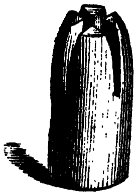


FIG. 74.

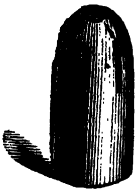


FIG. 75.

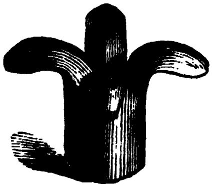


FIG. 76.

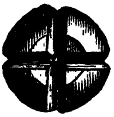


FIG. 77.

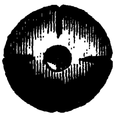


FIG. 78.

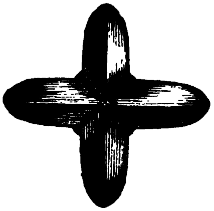


FIG. 79.

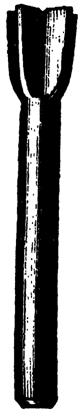


FIG. 80.

LORD KEANE'S CROSS-CUT BULLET.

There is a kind of Express bullet, other than the one shown in the sketches of cartridges previously given, that calls for special notice, as it is growing slowly into popularity, particularly in the United States; that is the "cross-cut" bullet identified in this country with the name of Lord Keane, who, we believe, first generally introduced it here and in India. Besides dispensing with the copper tube, this bullet, while possessing fully the Express qualification of expanding and inflicting a severe wound, lends itself with great facility to the use of a solid bullet fired from the same rifle with the same sighting. That the use of a solid bullet under some circumstances would be highly advantageous is generally admitted, either upon other than soft-bodied animals, or when, in the latter case, it is desirable to preserve as much as possible the skin or carcase from needless injury. Did the solid bullet, when so used, require other than the same sighting, &c., as the expanding one, the sportsman could not readily avail himself of its advantages; but the cross-cut and solid bullets practically interchange. On the opposite page are shown illustrations of a ·450 Express cross-cut bullet in different stages, Fig. 74 showing the bullet just as it leaves the mould after casting, the cuts having been formed by the winged "core-peg," shown in Fig. 80, that replaces the ordinary cylindrical one used when casting Express bullets with hollow points merely. Fig 75 shows the bullet after "swedging," with the cuts partially closed up so that no premature opening of the same shall occur before striking. Fig. 76 gives some idea of the action of the bullet within the body of the animal. Figs. 77, 78, and 79 are merely views in plan of the figures above them. When machine made, the cuts are generally sawn in the bullet prior to the final swedging process.

The smaller solid bullets shown in the illustrations of ·425 cal. and other similar cartridges call for no special remark, their structure being fully shown in the drawings; and it is only necessary to mention, without description here, the solid elongated bullet for mid-range or Cape rifles, as such projectiles will be found fully treated in the second part of this volume, that on "Match Rifles." There is, however, a recently-introduced improvement in rifle bullets that may prove of value for sporting purposes, namely, one, the novel feature of which shows an effort on the part of the designers to reduce the friction and consequent waste of power involved in passing bullets of the usual construction through the barrel in the act of firing. This is proposed to be done by reducing the bearing surface of the cylindrical portion of the bullet by "fluting" it with a number of longitudinal grooves, thus leaving the ribbed surface only to come into contact with the internal surface of the barrel. This bullet can either be used with or without a paper jacket. Below are sketches of a ·500 cal. cross-cut bullet of this kind, Fig. 81 being a side elevation, Fig. 82 a vertical section, and Fig. 83 a cross section of the ball. As far as the experimental trials have hitherto gone there is reason to believe that the desired end will be obtained, at least to some extent.

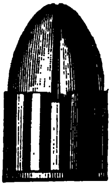


Fig. 81.

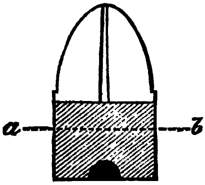


Fig. 82.

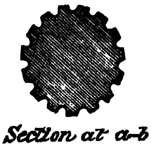


Fig. 83.

This bullet is manufactured by the Birmingham Small Arms and Metal Company, Limited.

Having now reviewed in the manner and order I proposed the various current kinds of sporting rifle ammunition, I cannot do better than place before my readers, in a tabular form, the matter we have had under our notice during this chapter—that is, a list of the various kinds now in use, of cartridges wholly adapted for the destruction of game, with their charges of powder and weights of bullet when possible.

## TABLE OF SPORTING RIFLE CARTRIDGES WITH ELEY-BOXER TAPER COILED SHELLS—CURRENTLY IN USE, AND BELONGING TO THE EXPRESS CLASS.

| Calibre. | Weight of Powder. | Weight of Bullet. | Remarks. |
|---|---|---|---|
| | Grains. | Grains. | |
| ·577 | 140 | 480 | Bullet generally cannelured. |
| ·500 | 120 | 350 | ,, paper covered. |
| ·450 | 110 | 275 | ,, ,, |
| ·400 | 85 | 210 | ,, ,, little used. |
| ·360 | 40 | 150 | ,, generally cannelured, little used. |

## SPORTING RIFLE CARTRIDGES WITH SOLID-DRAWN METAL SHELLS, ALSO BELONGING TO THE EXPRESS CLASS.

| Calibre. | Weight of Powder. | Weight of Bullet. | Remarks. |
|---|---|---|---|
| | Grains. | Grains. | |
| ·577 | 160 | 480 to 600 | Taper shell, patched bullet generally. |
| ·500 | 130 | 350 to 435 | ,, ,, |
| ·500 | 130 | 350 to 435 | Bottled shell ,, |
| ·500 | 160 | 350 to 435 | ,, ,,<br>Magnum. |
| ·450 | 150 | 275 to 325 | Bottled shell ,, |
| ·450 | 115 to 125 | 275 to 325 | Taper shell ,, |
| ·450 | 110 to 115 | 275 to 325 | Bottled shell ,, |
| ·400 | 77 to 82 | 210 to 250 | ,, ,, |
| ·360 | 40 to 45 | 150 | Taper shell, cannelured bullet. |

## SPORTING RIFLE CARTRIDGES FOR LARGE BORES WITH PASTEBOARD SHELLS.

| Calibre. | Weight of Powder. | Weight of Bullet. | Remarks. |
|---|---|---|---|
| | Drams. | Drams. | |
| 12 | 4 to 7 | Various | Generally solid spherical bullets, but sometimes conical ones of varying weight and style. |
| 10 | 6 to 8 | ,, | |
| 8 | 7 to 10 | ,, | |
| 4 | 9 to 14 | ,, | |

### Sporting Rifle Cartridges with Solid Drawn Metal Shells belonging to the Small Game and Rook Rifle Class.

| Calibre. | Weight of Powder. | Weight of Bullet. | Remarks. |
|---|---|---|---|
| | Grains. | Grains. | |
| ·458 | 55 | 380 | Bottled shell, solid bullet, paper covered. |
| ·425 | 30 | 230 | Taper shell, cannelured solid bullet. |
| ·360 (No. 5) | 15 | 130 | ,, ,, |
| ·300 or ·295 | 10 | 80 | ,, ,, |
| ·230 ("Morris") | 4 | 40 | Bottled shell. |
| ·220 (Winchester) | 4 | 30 | Rim fire, copper shell. |

### The Manufacture of Solid-drawn Cartridge Shells.

I will now give some account of the leading processes employed in elaborating solid-drawn cartridge shells from the plain disk of metal cut from the sheet or strip that has been reduced from the ingot of cast metal by the process of rolling it down to the required gauge or thickness. On the opposite page is shown with sufficient accuracy the principal varying steps in the development of the shell from its earliest stage; some little exaggeration in the thickness of the walls of each section shown has been found necessary to enable the unpractised eye to readily appreciate the gradual approach to the finished article, which in this case is a ·577 so-called Express taper shell. When the "bottle neck" is produced, it is a subsequent operation to any shown in the illustration, and is only a modification of the "tapering" process. Fig. 84 shows the circular "blank" or metal disk, also an edge view of the same; Fig. 85 the result of the first "cupping" process; Fig. 86 a still farther advance toward the tube—it will be noted that while the sides are gradually reduced in thickness and increased in length, the base or bottom of each cup remains the original thickness of the disk in Fig. 84. Figs. 87, 88, and 89 only show successive stages or "draws"

*Fig. 84.*

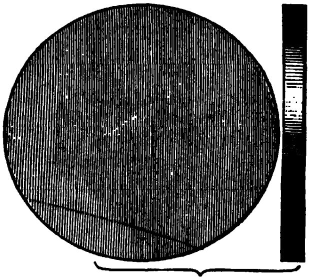


*Fig. 85.*

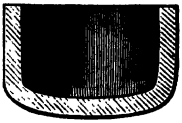


*Fig. 86.*

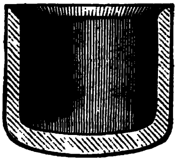


*Fig. 87.*

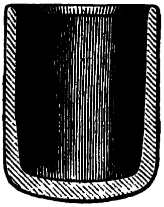


*Fig. 88.*

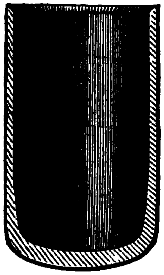
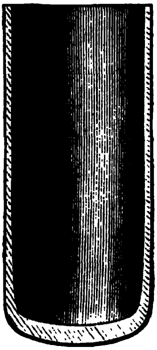


*Fig. 89*



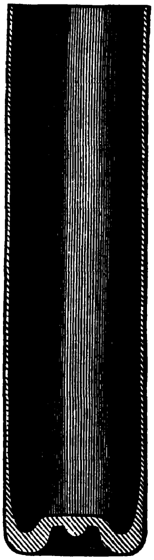


*Fig. 90.*

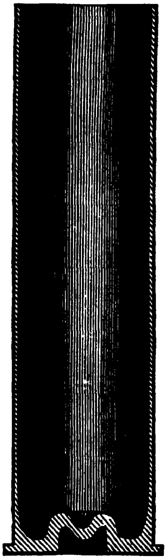


*Fig. 91.*

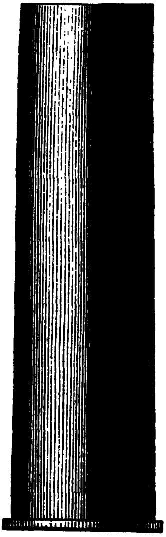


*Fig. 92.*

approaching each one more nearly to the desired end. In Fig. 90 we have the tube drawn to its full length, or rather more, to admit of any unsound edges being trimmed off; and further, the "cap chamber" is approximately formed, and the adjacent metal so disposed as to admit of the "head" and rim of the shell being formed as in Fig. 91, the cap chamber and its raised anvil also receiving the finishing touches. There is now nothing left to be done but the piercing of the flash-holes and cutting down to length and "tapering," which latter process has been applied to the finished shell shown in Fig. 92, and is carried out simply by forcing a suitably-formed die upon the shell when a parallel tube, as in Fig. 91, when it assumes the form of the die, keeping the same permanently on the withdrawal of the latter. It would be out of place in this volume to give the details involved in carrying out the above very ingenious processes, requiring as they do the use of most powerful and complicated machinery of a costly description; though, did my space permit, it would be found a most interesting subject. During the "drawing" and "heading" processes it is necessary from time to time to anneal the shells, as the severe crushing action to which they are subjected in passing through the machines renders the metal hard and brittle, and therefore liable to fracture. As a purely machine-made article, the solid drawn metal cartridge-shell would not now be obtainable by the sportsman in its present perfect state and numerous varieties if the manufacturers of these articles had not been stimulated by large contracts from foreign Governments to improve both their machinery and the details of the manufacture until the present stage has been reached; and, considering the costly plant employed, the minute accuracy of gauge maintained in the articles produced, the working capacity of the same, and the intrinsic value of the material employed, one can scarcely imagine a cheaper manufactured article than a solid drawn metal cartridge-shell.

### THE "CHAMBER" OR CARTRIDGE RECESS.

It is well known that in all modern breechloaders a recess is cut in the breech end of the barrel for the reception of the cartridges; this is required to be of such suitable form and size in rifles as will, while admitting of some slight variation in the ammunition, so nearly approach an absolute "fit" with the same as to obviate all chance of gas escape, or any disfigurement of the shell, and also to avoid perhaps the worst fault of all—the want of agreement between the respective axes of the cartridge and the barrel.

The production of this desired result is attained by the employment of suitably-formed tools or "bits" so applied as to remove the surplus metal, great care being taken throughout the entire process; indeed, there are few things more characteristic of the modes employed by a rifle-maker than his methods of proportioning the chambers of his rifles to suit their cartridges. As the entire process is, though of great importance, but a mere workshop detail, it is unnecessary to further remark upon it.

# CHAPTER IX.

## THE SPORTING RIFLE—ITS ADJUSTMENT, &C.

We have now arrived at that stage in the development of our weapon when the next question to be considered is the "sighting," or the arrangements by which we may so direct our fire as to insure striking the object aimed at. The first step involves the selection of suitable "sights," as the aiming details are called, together with their proper adjustment to the arm and its capabilities; and, in double rifles, the farther adjustment of each barrel of the pair to their common line of sight or aim—a process known as "regulating." After explaining, in connection with these processes, the errors incidental to the defective use of the weapon while being tested at the target, and likely to reappear with its use in the field, I shall give some practical information upon methods by which the sportsman can test his rifle and ammunition and their values in the matters of accuracy and trajectory. For reasons before stated, I shall continue to consider rifles of the Express type in preference to others used for sporting purposes; and if, during my remarks, I shall appear to dwell more upon experiences derived from firing rifles at a target than in actually using them upon game, it must be remembered that it is the former style of using the rifle which must be resorted to for all accurate information on the points in question; and, unless confidence in the weapon and its powers be obtained by practice at the target, it will probably take a more or less long and vexatious experience in the field before that control is established over the weapon which is so necessary to its thoroughly satisfactory use.

## SIGHTS.

The sights used on sporting rifles are of various patterns, according to the fancies of the maker or the requirements of the user. They can, however, be divided into two classes: "open" sights and aperture or "peep" sights—the former being by far the most generally used kind; indeed, the latter appear to be of very limited use in actual sport, though valuable in target practice, as will be explained in our section on Match Rifles. Although there is no question of the value of aperture sights in *localising* the aim to an extraordinary degree of accuracy, still, the loss of light involved by their use, and the time taken in manipulating them either in adjustment or aim-taking, must confine their use to very special cases when in the field.

The sights of rifles are always two in number, the "back-sight" or one nearest the firer's eye, and the "front-sight" or fore-sight, near the muzzle end of the weapon—their use being, as is well known, to assist the firer in the "alignment" of his weapon upon a third more distant object. The back-sight is usually so constructed as to offer to the eye a metal bar, or "standard," set at right angles to the line of aim, with a notch or V cut in its upper edge, of varying depth or width according to desire. The favourite form of front-sight in sporting rifles is some modification of what is called the "bead," and is inserted or attached as near as convenient to the muzzle end of the upper surface of the barrel, or rib of the latter when double; this bead is so made as to offer to the eye when aiming a minute circular disc set upon a very thin stem. The usual diameter of the former is about ·04 or ·05 of an inch—this size not being too large to prevent accurate aim being taken at a fairly small object, or so small as to fatigue the eye, or to require an extremely attenuated stem, which would be obviously objectionable, although the body of the entire sight is continued lengthwise for the purpose of obtaining as much strength as possible.

When a bead of this size is aligned upon a target 100 yards distant, it will be found about equal to a bullseye thereon of 4in. in diameter. The position of the back-sight upon a sporting rifle, in relation to that of the front-sight and the eye of the firer, has caused a considerable variety of opinion among rifle-makers. Those of the older school kept the two sights as far apart as could be conveniently managed, with the idea of securing the greatest possible accuracy of alignment upon the object aimed at. So far so good; but the optical disadvantages attending the use of a sight too near the eye—resulting from the great change of focus required in the endeavour to see with equal clearness both the near and distant object—has induced rifle-makers of late to remove the back-sight nearer to the front-sight, thereby very much improving the clearness of aim and but very slightly deteriorating the accuracy of alignment; thus, we find on modern sporting rifles the back-sight situated about half way between the eye and the front-sight.

The back-sight should be rather broad, so as to give the wide upper edge, so useful in assisting the firer to hold his rifle "square," that is, with both axes of the barrels in the same transverse horizontal plane—rather an important matter with a double rifle. As to the V, a rather narrow one of moderate depth is preferable in some respects for target practice, whereas a more open one is generally preferred for use in the field; and the latter no doubt enables a quicker aim to be taken from its affording a more extensive view all round the object aimed at. A V that includes an angle of 120°, or thereabout, seems to be the most generally useful. Some sportsmen say that they prefer the flat bar without any V, but with the centre indicated by a bright metal line only. It is probable in such a case, more especially with hurried shots, that the bead is *not* always coincident with the metal line, thus leading to an erroneous aim being taken. This metal line is very generally used in combination with the V, being carried up the face of the sight and terminating at the bottom of the notch. When the sun is bright, and in the rear of the firer, this line does not always facilitate the aim, but it is mainly valuable in shadowed situations. The face of the foresight bead is also covered with the same white metal, and for a similar purpose, showing upon the dark body of an animal in a remarkably clear manner; but when used in bright sunlight it is open to the objection previously urged. Front-sights entirely made of ivory or faced therewith are also used, and have this advantage over the metal, that, though white, there is no glitter shown by them. And, in some cases, triangular pieces of the same material are let in the face of the back-sight, the apex of the triangle coinciding with the bottom of V or centre of bar, if without a notch. Of course, if any of these sights have to be used at an ordinary white target, they have to be blacked or dulled previously.

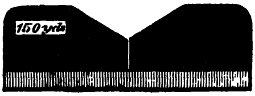


FIG. 93.

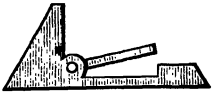


FIG. 94.

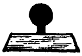


FIG. 95.

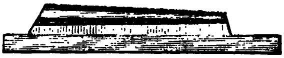


FIG. 96.

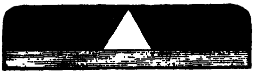


FIG. 97.

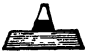


FIG. 98.

Above are sketches of sights enlarged to rather more than their proper sizes, Figs. 93 to 96 being a side and front view of a set of Express rifle sights of ordinary pattern, and Figs. 97 and 98 a front view of ivory mounted back and front-sights for a similar rifle.

When these sights are attached to the barrels of the rifle, the back-sight is set as much higher than the front-sight, as compared with the axis of the barrels, as to compensate for the drop of bullet at a determinate distance—say 100 yards range—giving what is called the "angle of elevation;" so that at all intermediate points the path of the bullet is *above* the line of aim—most markedly so at about half way, or at the 50 yards distance. At a distance superior to the one the sights are adjusted to (say 150 yards), the bullet strikes proportionately *lower* than the line of aim; but I shall be able to show that, with such an Express combination of rifle and ammunition as most fully illustrates the system, this up and down variation will not much exceed *four* inches, which is as near as most men can hold when firing without artificial

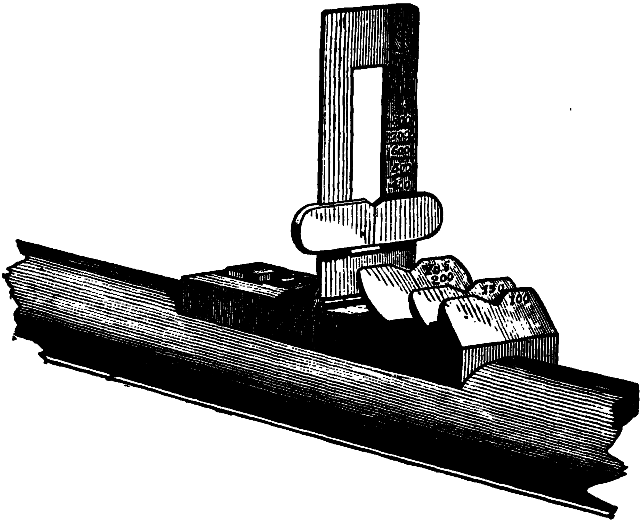


Fig. 99.

assistance in the shape of rests, &c. In a case where the arm is required to be used at a still longer range, a "leaf" or extra upright (of such height as to give the desired increase in angle of elevation) is fitted to the back-sight upon a hinge joint, so as to fold down out of the way (see Fig. 94).

Most rifles of other than Express capabilities have sights fitted with a series of these leaves, progressively increasing in height to suit the lengthening of the ranges; and sometimes what is called a "tangent" leaf of some length is combined with these sights, having a slotted aperture through which aim is taken over a "slide" capable of adjustment to the desired elevation, in a precisely similar manner to that of the long range military pattern sight explained in the chapters on Match Rifles (see annexed Fig. 99).

I may here refer to a type of the "peep" sight tolerably popular in the United States, and of late rather freely introduced into this country. I allude to the so-called "Lyman" aperture back-sight and the "Beach" combination front-sight, generally used together. This aperture back-sight has an eyepiece of small size, acting in but the slightest manner as a screen that should exclude all the extraneous light from the firer's eye when aiming, other than that passing through the central hole or "peep;" thus its construction in this respect is the very opposite to the aperture sights hitherto used in this country, which latter have always had the peep-hole surrounded by an ample screen, thus keeping the eye undisturbed during the process of aiming. In the Lyman sight variations in elevation are obtained by raising or lowering the graduated pillar carrying the eyepiece by means of a screwed nut that can be moved by the finger and thumb in the desired direction; the whole is mounted upon the "hand" of the rifle as a rule, and can be folded down out of the way by means of an ordinary hinge joint controlled by a spring in the usual manner. The "Beach" front-sight presents two aspects, one a small bead centrally mounted in a nearly circular hoop or shade—useful both for protecting the slenderly-proportioned bead and its stalk, and for assisting the aim by affording an easy object as an aid to the "centering" of the bead in the eye-piece of the aperture back-sight. This entire arrangement is so mounted on a small joint that it can be folded down upon the barrel, exposing then a small projection that can be used as the ordinary bead for aiming with the open back-sight; though, should such a back-sight be used upon a rifle in combination with the "Lyman," it should not have a fixed "standard" elevation, but folding leaves, so that these may be shut down, and leave an unobstructed view when the aperture sight is used. These sights have no lateral adjustment, consequently they can only be accurately "set" for short distances, any allowances required for wind influence upon the bullet being given by the usual mode of "aiming off" the estimated amount required.

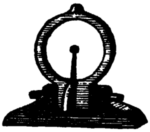


FIG. 100.

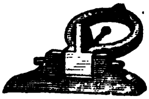


FIG. 101.

BEACH FRONT-SIGHT.

Figs. 100 and 101 show the Beach front-sight; first, the sight as arranged for use with the aperture back-sight; and also shut down with the stud ready for use with the ordinary back-sight.

Figs. 104 and 105 give a view of the Lyman sight, also a section of the same, showing the mode of raising and lowering the pillar, and the attachment of the auxiliary eye-piece with a smaller sized aperture than that of the normal one in the head of the pillar, and suitable for use only in very fine lights.

It will be easily seen that the application of these sights to the purposes of actual sport is exceedingly limited. I need only allude to some patterns of sights that have been produced from time to time with the intention of blending together as much as possible the good points of both peep and open sights; these have generally resulted in failure from a sporting point of view, for, though probably giving some slight advantage at the target, they needlessly hamper in the field that clear rapidity of aim so practically valuable on most occasions.

There is a kind of open bead front-sight much used upon a certain class of sporting rifles, that is, one in which the bead (generally slighter than usual) is protected by side wings or flanges as shown in the figure.

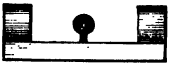


FIG. 102.

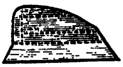


FIG. 103.

FRONT-SIGHT WITH SIDE WINGS.

This is a compromise between the bead alone and the same inclosed in the circular shade, and to some extent is a better arrangement than either, as the bead is not so exposed to hard usage as in the former case, while the aim is less likely to be embarrassed than in the latter, though instances have occurred where, in taking a hurried shot, one of the side wings has been used for the bead itself.

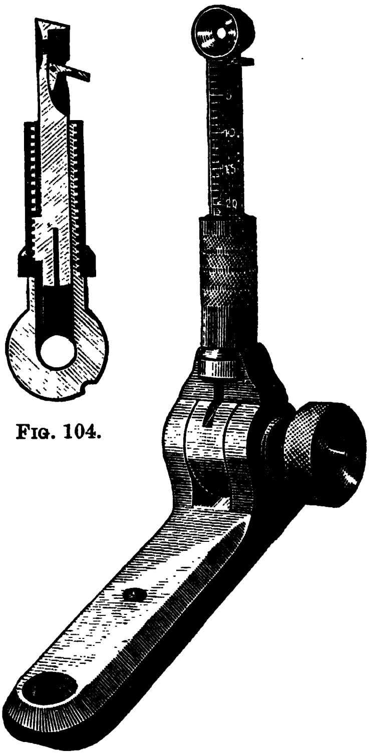


FIG. 104.

FIG. 105. LYMAN BACK-SIGHT.

A sight never much used in this country but rather more popular in the United States, where it is used upon rifles for short range match firing, is the "telescope" sight, consisting of a telescope of moderate power and aperture, mounted upon, or at the side of the rifle. When required for use at the longer ranges, the latter method of mounting offers the greatest facilities for the introduction of those mechanical details necessary to the adjustments for elevation and wind allowance; but, for the shorter sporting ranges, the telescope answers sufficiently if attached to the rifle upon the upper surface of the barrel, when no provision is made for altering the angle of the instrument, except that it is fitted with three fine lines in the field of view, one vertical and the other two horizontal, some little distance apart. Thus for the short range of, say, 100 yards, the spot aimed at is intersected by the crossing of the *upper* horizontal line with the vertical one, while at the 200 yards range the *lower* horizontal line is used in

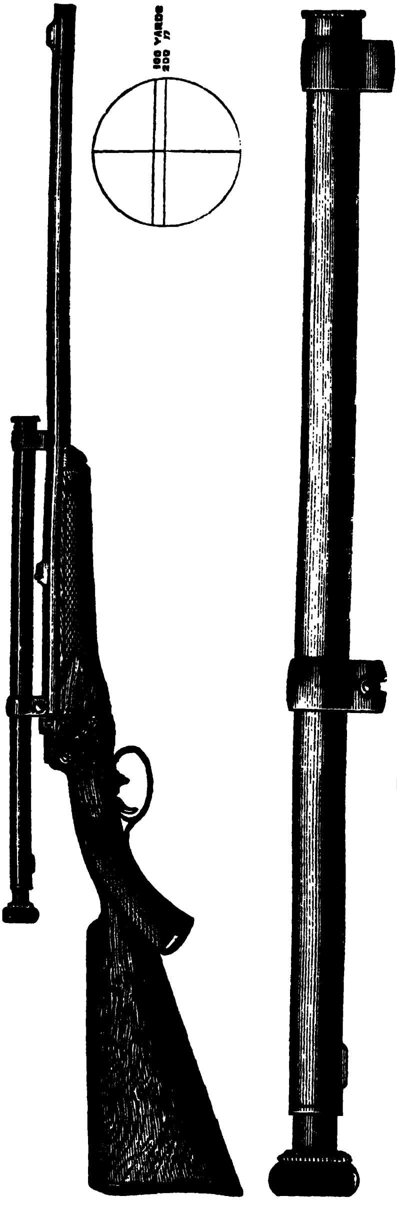


FIG. 106. FRASER'S TELESCOPE RIFLE.

the same manner—the space between these two lines being equal to the amount of elevation required by the rifle from the one distance to the other. These sights were in use by American rifle-makers at a very early period, and were introduced into this country by Lieut.-Col. Davidson, about 1834. Fig. 106 shows a sporting rifle by Messrs. D. and J. Fraser, of Edinburgh, fitted with such a sight in its most modern form—the rifle having only been made during the late season of 1883, and having their new patent breech action, to be found fully described and illustrated in the Match Rifle section of this volume.

That the use of telescopic sights very much improve the clearness of definition, and consequently the accuracy of aim, is obviously unquestionable; but their extra cost and delicacy will doubtless prevent their use from ever becoming general among sportsmen.

Some ingenious devices have been invented for the purpose of facilitating the almost instantaneous changes of elevation sometimes required in the field, but the majority of them are of but dubious value. One of the best is that designed by Mr. John Rigby, and shown in Fig. 107.

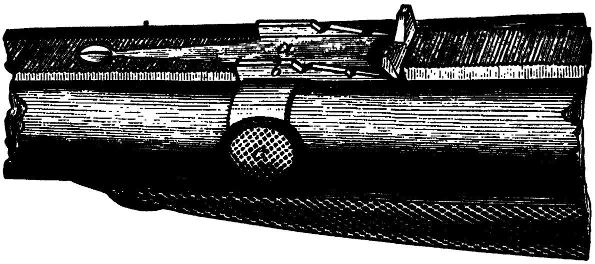


FIG. 107. RIGBY'S SIGHT.

The sight is shown as upon a double rifle, and is in fact a steel spring, one end being fastened to the rib by a screw and the other set at right angles to the long elastic portion, and shaped to resemble an ordinary back-sight. On each side of the rib slide notched inclined surfaces whose motion is controlled by a thumb-piece; these inclines engage beneath the standard of the sight, and, by drawing them towards the firer, the sight is raised—an operation that can be performed while the rifle is at the shoulder; thus elevation can be instantaneously obtained for an increased range.

## ADJUSTING THE RIFLE.

In proceeding to regulate and adjust our rifle (preferably for illustration a Double Express one) by shooting the same at a target, it is of course imperative that every technical detail involved in the process of firing the weapon should be fully attended to, as it is quite possible that the existence of an apparently trifling mechanical imperfection may seriously invalidate the results of our labour in this most important stage of our inquiry. To enumerate all, or even the chief, points to be attended to in this respect would be wearisome to the reader, consisting as they do of those mere technicalities so often *assumed* to be all right, and really only known in all their intrinsic importance to the experienced rifle-maker.

Having the rifle sighted and in a fit state for shooting, and the ammunition properly loaded, the next point to be considered is that of the support for the firer and his rifle—the "rest" used when regulating rifles fired from the shoulder. This need be but a simple affair—all that is absolutely necessary being a firm support for the elbows, against which he may lean the upper part of his body; and also a support of a sound inelastic kind for the barrels of the rifle—usually a sandbag or similar article. I may here be permitted to allude to the "machine rest" for firing rifles therefrom during the regulating process, almost identical in structure with the "rest" for shot guns shown facing page 46, Vol. I. That this rest would be an important auxiliary to the rifle-maker there is no doubt whatever, but, in its present stage of development, it is not quite capable of successfully coping with the great variety at present existing in sporting rifles and their ammunition—the varying details of which require differing and particular manipulation of the rest for nearly each individual variety; still, I have every belief that in time, when the matter has received more attention than it has yet been able to obtain, the machine rest will become at least an important auxiliary assistance to shoulder firing in the process of regulating double rifles.

In the earlier stages of the shooting of our rifle, it is better, for many reasons, to use an iron plate as a target. This should be of substantial thickness, and of such a size as to render missing it difficult even with our weapon in its crudest stage. Before commencing to shoot, we must premise that the operator be so sufficiently acquainted with the art of rifle shooting as to be fairly able to accurately *repeat* his aim—that is, not from carelessness or want of practice to vary the amount of foresight seen and used in aiming, neither to fail in centering the same properly in the V, or upon the line of the back-sight. He must also be capable of "letting off" or discharging the rifle by a steady even pressure of the finger upon the trigger, without subjecting this latter to the influence of jerk or tremor. These apparently simple qualifications are not possessed in perfection as generally as supposed by many who believe themselves to be fairly "steady" shots; and, indeed, they can only fully belong to anyone while in perfect health—though a degree of robustness rather militates against the finest rifle shooting form. The beneficial effects of practice in accustoming the muscles of the firer to a rigid mental control is, as is well known, of the greatest value in rifle shooting.

In holding the rifle in position for firing, great care should be taken to keep it "square;" if this be not attended to, great trouble and expenditure of ammunition may be incurred before satisfactory results are arrived at.

The first series of shots may be fired from each barrel alternately without regard to the position of the respective groups to each other. This should test the shooting value of each barrel, and also that of the ammunition; and, should it terminate satisfactorily, the group obtained from each barrel will have the least amount of deviation ever likely to be obtained from either barrel during any subsequent shooting that may take place, because each tube is now *individually* in its most perfect state, though the two groups may be some distance apart.

Should the shooting at this stage *not* be considered good enough, the requisite correction should be made either in the workmanship of the barrel or the details of the ammunition, as observation and experience may determine. Except in rather rare cases, however well each barrel may shoot, there is always some want of agreement between the centres of the two groups obtained and the common point of aim. This error may be simple, as when the centres of impact are upon the same horizontal line, but inches or feet apart; or compound, as when, in addition, the groups differ vertically. In the former case the barrels are said to either "cross" when the right-hand barrel throws its shot to the left, or *vice-versâ,* or they may shoot "wide"—that is, each barrel throwing its shot to its own side of the point aimed at, but more or less away from it. These faults are caused by the barrels not inclining toward their common centre, as required by the ammunition with which they fired, as explained in the chapter on Construction, page 242. The makers of double rifles some years ago were sadly puzzled with this difficulty, though, as much smaller charges were then fashionable in comparison with those now used, the matter was really much more simple as to its conditions than it now is.

It will be easily seen that, when a shot is fired from, say, the right-hand barrel, the blow of the recoil is sustained by the same side of the common axis of the piece. Thus the weapon receives an amount of motion, not only in the direction of the backward thrust, but also an outward swing, as it were, to the right, the centre of which would be the point of contact between the butt of the weapon and the firer's shoulder, were either the latter immoveable or the arm itself a rigid mass; but as, from its form and compound structure of wood and iron, it possesses a certain amount of elasticity, and, on the other hand, the shoulder gives way materially, a very complex motion is the result—the most important feature in relation to the point under consideration being, that the muzzle of the particular barrel of the pair moves in an outward direction a certain amount at or about the instant the bullet is passing therefrom during firing. There is some reason to believe that the centre of this motion is situated about the grip or "hand" of the stock, and that the time question prevents any movement of the shoulder ultimately due to recoil from influencing the bullet in the manner described. Fortunately, from the same cause, the bullet has left the barrel before any great amount of this motion has occurred to the muzzle, or we should have to proportionately increase the angle of inclination of the barrels to each other. As it is, barrels required to shoot together upon one spot 100 yards distant, frequently have to be so jointed that their respective axes intersect at ten or fifteen yards from the muzzles—an arrangement that would result in their fire crossing upwards of two feet or so at the longer distance, were it not for the operation of the recoil in the manner described. It can thus be easily understood that if any modification of the charges used with such a rifle take place in the direction of materially lessening the recoil, the barrels will thereupon shoot so as to cross their fire. On the other hand, if the charge be so altered as to increase the recoil, the contrary effect will be produced. Also, if any structural alteration be made in the arm affecting its rigidity as when regulated, we must in consequence expect some change, more or less marked, to be observed in its shooting.

Our object now is to bring together the group of shots from each barrel into one; and, to effect this purpose, each tube must be submitted to an amount of flexure sufficiently altering the line of fire to bring about the desired result. This treatment is rendered necessary by the fact of the barrels at their breech end being firmly attached together—indeed, rendered practically one; therefore it is only by manipulating the forward portion of them that we can in any way modify their original errors of construction.

It will appear to many that the accuracy of each respective barrel must suffer from this treatment; and no doubt, if carried to excess or carelessly performed, the permanent deterioration of the barrel so treated is a certain result. But if in the first instance the barrels have been properly jointed together in accordance with formulæ derived from previous experiments correctly carried out, the amount of alteration required is so small as to not seriously, or even appreciably, affect the shooting of the barrel as far as accuracy is concerned. We are in this respect rather fortunate in the fact that the short projectiles commonly used in sporting rifles travel almost as well along a tube having a curvature of extremely large radius, as along one perfectly straight; but if the operation of regulating be so performed that a curve of small radius be established, or what is called a "short crook," then the arrangement becomes defective. Although for the time the shots are thrown near the desired spot, the tendency to radial dispersion in a group obtained from such a barrel is always greater than in one fired from a barrel perfectly straight—other things of course being equal. This is not the only objection existing against barrels so improperly treated. When we consider the unequal wear and tear upon certain portions of the bore of such barrels, we need not be surprised to find that, after some year or so of hard use, they no longer shoot together as when first adjusted, but require regulating anew.

The manner of effecting the adjustment of double rifle barrels is briefly as follows: The errors in jointing having been made manifest upon the target, the barrels are dismounted and suitably arranged for alteration; they are then heated for some distance along from the muzzle end gradually and sufficiently to melt the tin used as a solder for attaching the two tubes and the upper and lower ribs together. While in this state, it is possible to alter the relative positions of the tubes to each other at the will of the operator. The requisite alteration having been made, the barrels are allowed to cool, and are again fired, when, if not found satisfactory, the process is repeated.

There are various modes of effecting the requisite degree of adjustment, but they all resolve themselves into a system of patient "trial and error," continued and repeated until the desired end be obtained; though, for obvious reasons, the fewer stages there are in this process the better for the ultimate perfection of the weapon. In conducting this operation conclusive proof is afforded that the entire structure of the weapon has a considerable influence over the shooting obtained therefrom, though it is generally the opinion that the barrels alone influence the accuracy of fire. Of course this is the case to a very great extent, yet it is not an uncommon thing for some considerable time and anxiety of mind to be spent on the alteration, adjustment, and re-adjustment of a pair of rifle barrels, when the real source of trouble lies in a defectively fitting breech action, or an improperly attached stock.

When at length the mutual adjustment of both barrels of the pair is such that, from a series of shots fired alternately from each one, with the same aim, a group is obtained in which no bias of either barrel can be detected in any direction whatever, then the regulating process may be considered complete; providing the space occupied by this group be not unduly enlarged in size when compared with the space covered by either one of the approved groups, obtained from either barrel before the regulating process began. If the contrary be the case, it shows that the rifle has suffered more than necessary from the process, though the relative degree of excellence in grouping its shots shown by any rifle depends somewhat upon the skill of the firer.

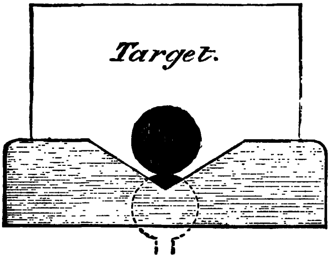
The back-sight, hitherto kept a little higher than it should finally be, may now be lowered to its proper height, so that the "elevation" of the rifle at this standard range shall be true; this is the case when a horizontal line, drawn across the point aimed at, cuts the centre or point of mean impact of the group of shots fired at this range. When the sights are truly aligned upon the target at the aiming spot or bullseye, the lower edge of this latter is the point of aim; and, if the weapon is accurately sighted, the shots should group around that spot. If this be not so, and the centre of the group be materially *above* this point, the result is that, at any shorter distance the rifle may be fired at, the shots will strike so high *above* the mark as to seriously impair the efficiency of the weapon; indeed, most sportsmen consider this defect a most objectionable one, though, for the purpose of partially compensating for the bullet drop at longer ranges, rifles are frequently so sighted as to shoot in this manner.

When the bullseye is used for SCORING purposes as well as an aiming spot, the sights of course require to be so adjusted as to allow the bullet to strike its centre—thus giving the best chance for the entire group striking within its circumference.

### AIMING.

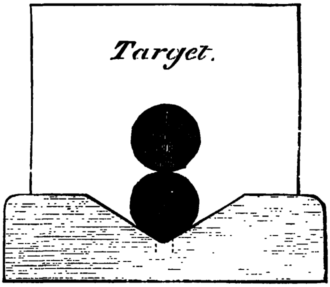
Some varieties of opinion exist as to the proper mode of aiming with sporting sights—some inclining towards what is called a "fine sight," and others favouring the "full sight" system of aim. The annexed sketches illustrate the two methods perhaps as well as the difficult nature of the subject permits it to be shown by a woodcut.

It will be seen that, though the "fine sight" in a good light and under favourable conditions is a most accurate method of aiming, especially at small objects, and when a leisurely aim can be taken, still there is much to be said in favour of the "full sight," as it does not try the eye so much as the fine sight, while it affords a better view around the object aimed at, and is more suitable for dull lights and hurried shots. In target practice it is considered an improper way to so aim with sporting sights as to *cover* the bullseye with the bead of the front-sight (only with a certain kind of aperture front-sight), for the obvious reason that it is next to impossible to tell whether the bulls-eye be only *just* covered by the sight, or whether the latter overlaps it, and to what extent. But in actual sport the front-sight is very frequently placed, in aiming, upon the exact spot of the body of the



*Fine sight*

FIG. 108.



*Full sight*

FIG. 109.

animal that it is intended the bullet shall strike; and under usual circumstances this mode of aiming may be successfully practised, as the remainder of the figure of the animal acts as a check or set-off, as it were, to the point aimed at. As to the difference in elevation caused by taking a "full" sight, as compared with that obtained by using a "fine" sight, it of course largely depends—first, upon the relative size of the front-sight bead; and, secondly, how much of this bead be taken in when what the firer calls a fine sight be used. This latter varies considerably with different individuals; and the better plan is for each sportsman to ascertain this matter for himself, by a few shots with each kind of sight at a target.

A common source of error in firing rifles carrying heavy powder charges is that arising from the difficulty experienced in obtaining a clear aim after firing a few shots in moderately rapid succession. This is caused from the heat produced by the combustion of the powder being imparted to the barrels, and being thus transmitted to the surrounding air; this heated air produces a kind of "mirage," which, if allowed to arrive at a moderate degree of intensity by continuous firing, becomes very annoying, causing as it does the object aimed at to flicker and waver about in the most embarrassing manner. This trouble can be avoided by firing slowly, thus not allowing the barrels to become more than just perceptibly warm without getting them actually hot. It would also be possible to remedy this inconvenience by so raising the sights above the barrels as to avoid the stratum of heated air in contact with the latter; but, in addition to the structural objections there are to the adoption of this plan, there is also to be considered the fact that the higher the sights (and therefore the line of aim) be above the axes of the barrels, the more disastrous becomes the effect of slightly "canting" the rifle, or permitting any deviation in holding it other than truly "square."

Fortunately in sport a rapid series of shots is rarely or never required to be fired with a minute accuracy of aim.

## FOULING.

The question of "fouling," if not duly attended to, is a fertile source of inaccuracy of fire, especially with sporting rifles, on account of their usually large powder charges depositing a proportional amount of the solid products of combustion within the bore of the barrel. This deposit is increased in quantity, and rendered more unmanageable, if the powder used be of an inferior quality, or crushed and injured during the loading process or otherwise, as I have before remarked in Chapter VIII., page 309. On examining the interior of a rifle barrel after firing, by looking up it from the breech end, it will be noticed that the greater portion of the fouling is deposited upon the lower side of the bore, showing that these grosser particles have been acted upon by the force of gravity in taking up their relative position, in opposition to the finer deposit upon the remaining portion of the bore. I need scarcely say that if shots be fired from the rifle while it is held in other than the normal position, this gravitation of the heavier portion of the fouling will still take place to the then underside of bore.

The conclusions arrived at from the observation of this manner in which the fouling is deposited have led to the endeavour, on the part of rifle-makers, to prevent, as far as is practicable, these solid products from passing into the rifled portion of the barrel, and thus interfering with the passage of the bullet. With this view, cartridge shells of such an internal shape as to offer some mechanical means of retaining within them as much as possible of these objectionable portions of the fouling, are preferred. The bottle-shaped shell is for this purpose considered to be much superior to the merely taper shell. Though probably not originally designed with such intention, yet we may consider whatever value it may have in this respect as a set-off to some alleged objectionable features this shell is accused of—that is, increasing the recoil, and exerting additional strain upon the breech action as compared with the action of the taper form of shell employed with a similar charge. Not content with this property in the bottled shell, it has been the endeavour on the part of some to further intercept and retain more of this fouling by adding an internal ridge or fillet about the base of the neck of the cartridge where it joins the shoulder; but, as might have been expected, the increase in recoil caused by this arrangement quite destroyed its practical value. As can easily be understood, the amount of fouling retained by the fired shell is largely dependent upon its length as well as its form.

When, however, every possible precaution has been taken in these directions, we have still to confront the difficulty offered by a large amount of deposit being left in the barrel after each discharge, and what we have to do is to prevent this accumulating, and thereby, after several shots, unduly retarding the bullet fired when the maximum accumulation possible has been reached.

In my remarks on Waddings (page 310), I have indicated the most generally approved means of coping with this difficulty, most of which involve the application of "lubrication" in some form to the interior of the barrel with each successive discharge. It is found by experience, especially in sporting rifles, that this method works well, as, indeed, the existing conditions of the rifle during firing would seem to *demand* lubrication—there being great pressure, high speed, and a considerable amount of local heat, all simultaneously in operation; and when similar conditions exist in ordinary mechanical combinations, there is no hesitation shown in falling back upon the universally recognized remedy, that of applying lubrication.

Those authorities in the rifle world who are rather disposed to cavil at the employment in rifles, during firing, of this well-known agent for the reduction of friction, have generally acquired their experience in dealing with charges of powder that are relatively small, and consequently so much more easily managed in this respect. They are also, as a rule, disposed to unduly estimate the value of a "sweeping" wadding as compared with one of a more active lubricating nature—perhaps overlooking somewhat the fact that the bullet, especially when covered with a paper jacket and duly proportioned in all respects to its work, must of necessity perform a great share of the "sweeping" business, passing up the barrel, as it does, a complete "fit," and *in front* of the wadding. A barrel kept cool and moist internally by the action of the breath will suffer much less from the effects of fouling than one not so treated—all other things being equal.

It is to be noted that anything in the internal structure of the barrel, offering a mechanical obstruction to the onward rush of the dirt-laden powder gas, always causes the fouling to accumulate unduly at that point; and probably, from this cause mainly, one form of rifle groove may be preferable to another. Also we may reasonably assume that in barrels rifled upon a varying curve—the slow pitch occurring, as it does, at the breech end, and the grooving there running approximately parallel, or nearly so, to the path of the gas—less opportunity is consequently given for the fouling to lodge than would be the case with a sharp spirally cut groove forming a marked amount of angle to the action of the gas blast; and, therefore, under circumstances of imperfect lubrication, when no check of sufficient efficiency is supplied to restrain the accumulation of fouling about and just beyond the mouth of the chamber (always a dangerous spot), such a contrivance as that offered by the increasing spiral system of groove may be of some value.

### RECOIL.

Recoil is a matter much affecting the results obtained from a sporting rifle, acting, as it does, on both the firer and the rifle in various ways. As to its action upon the firer, there can be no doubt that a rifle having a severe amount of recoil is a great nuisance to its possessor. It may be quite true that, in the moment of excitement while firing at game, the recoil blow is not felt; but if, under circumstances where no excitement exists, a man be severely and unnecessarily punished with every shot he fires, can he become sufficiently acquainted with the qualities of his weapon?

The causes of undue recoil are several, the most usual being overloading the cartridge in proportion to the weight of the rifle; and this may result in either one of two ways—an excess of powder with a bullet of moderate weight, or a rather smaller quantity of the former with a decidedly heavier bullet. It can be shown that these opposite methods of overloading produce correspondingly different effects in the way of recoil. Setting aside the outward swerve of the barrels upon firing them one at a time—noticed in my remarks upon regulating (page 339), as only applicable to double rifles—the simultaneous movements of a recoiling rifle are distinctly two in number, viz., the backward thrust of the entire weapon, and the upward "jump" of the muzzle end of the barrels. It is the former movement that mainly inflicts the punishing blow upon the firer's shoulder, and, as might be expected from the facts stated at pp. 94–98, it is this motion that is intensified by the use of a heavy bullet.

It is, unfortunately, rather difficult to illustrate the actual effects of recoil upon the firer, as the usual method employed in measuring its amount only gives us the result or weight of the blow, without giving us the *speed* with which it is delivered—a most important point in treating of the effect of a blow upon the firer's shoulder. This probably accounts for the differences observed in the amount of unpleasantness felt in firing two rifles whose recoil, as indicated by the spring balance, is within a few pounds of each other.

When a larger charge of powder and a lighter bullet is used, we can readily judge of the difference in the recoil blow from a rifle of the same weight, &c., as used in the opposite case; and we can further gauge the increase of "jump" by testing the performance of the rifle with varying charges. The effect of "jump" is produced by the bullet leaving the muzzle of the barrel while the latter is in motion both *backward* and *upward.* This effect has not hitherto been properly investigated, or fully understood in connexion with sporting rifles; though with field artillery a precisely similar result was observed and fully investigated by Sir J. Whitworth many years ago.* This peculiar effect (which, though apparently it seems so very accidental, is yet, if tolerable regularity in the loading of the cartridges fired be insisted upon, capable of exceeding uniformity in its manifestation) is due mainly not to any vibration, or "springing," of the barrels of the rifle, but to the upward leap of the weapon on firing, resulting from the shock of the explosion being received at a point wanting in stability, and much below the axis of the barrels or line of fire. When the rifle is fired from the shoulder rest with the sandbag support situated near the muzzle end of the piece, this latter being firmly held thereon, then the effect of "jump" is most palpable; while if the rifle be fired from the shoulder only, without other support than is afforded by the firer's left hand applied in the usual place near the breech end of the barrels, a slight reduction in the effect of the "jump" is apparent—probably on account of the rifle stock "buckling" a little across its weakest place, the grip, and thus allowing the muzzle to droop to a slight extent. That the considerations affecting angular value of elevations, bullet drop, &c., are much affected by this action of "jump" may be easily understood; but it varies with change of circumstances, and in the section upon the theory of projectiles it is necessarily disregarded in the various tabular statements, which are based on the assumption that the muzzle of the rifle is motionless during the passage of the bullet and at the moment the latter is launched into the air.

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* "Guns and Steel," by Sir J. Whitworth, Bart. London: Longmans, 1873, see page 60 *et seq.*

In proceeding to consider the next cause of error likely to be met with—variation of powder charges used—an illustration will be given of the amount of interference the "jump" action of recoil has with the theoretical laws governing the bullet's flight.

It will perhaps be unnecessary to allude to other causes producing undue recoil in rifles; these are mainly errors in constructive detail, not necessary to enumerate here, as too technical to be generally understood from a mere verbal description. A rifle with its stock of such dimensions and shape as to be unsuitable to the physical requirements of the firer will frequently inflict a more severe amount of recoil blow than the charge fired would seem to justify; therefore a rifle firing heavy charges should, if possible, be fitted to suit the firer with the greatest care, or it will always be a most objectionable tool in this respect.

### VARIATION OF LOAD.

In loading up cartridges the sportsman or his assistant may be occasionally careless, and so inaccurately measure the quantity of powder filled into each shell. I use the word measure, as, though weighed charges are invariably to be recommended where extreme accuracy be insisted upon, yet measuring, if carried out with proper appliances and moderate care, is quite sufficiently accurate for ordinary sporting purposes. Still, as an example of what may be expected to ensue if any material variation in the normal powder charge be made, either from accident or design, I give the illustration shown below (Fig. 110), which is a reduced copy of a cardboard target at which a double Express rifle has been fired, with cartridges loaded with three differing powder charges. To avoid unduly complicating the groups obtained, one barrel only of the rifle was used—the left hand one—*five* shots being fired with each charge, the point aimed at throughout being the lower edge of bullseye, and of course the same amount of sight being taken. The distance was 100 yards, the rifle a double Express, ·450 taper solid shell, the bullet used, a paper covered one 280gr. in weight; the rifle weighed nearly 9lb., and the barrels were 28in. long. The target is divided into 3in. squares, with a 4in. circular bullseye indicated

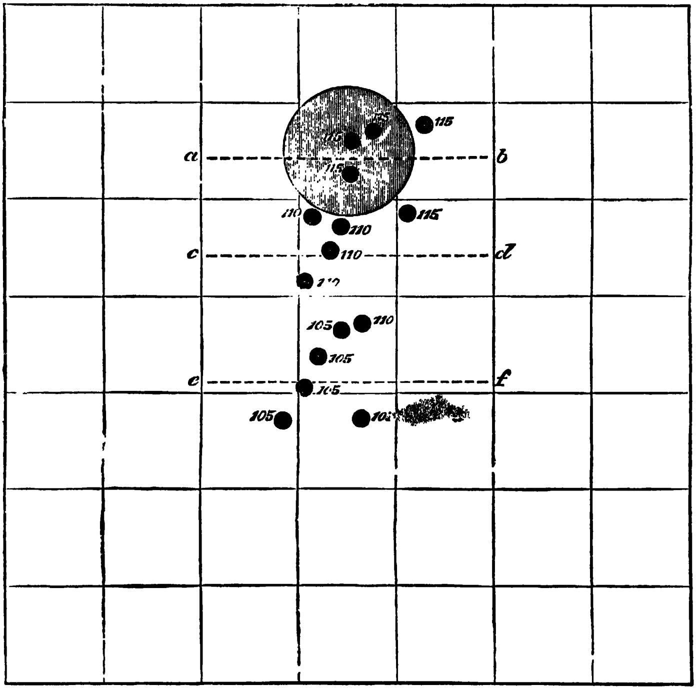

Fig. 110. Diagram of Different Powder Charges.

thereon. The dotted line *a b*, drawn a little below the centre of the bullseye, is a horizontal line cutting the point of mean impact of the shots fired with the 115gr. charge; the line *c d* serves a similar purpose for the 110gr. group; and *e f* the same for the group made with the 105gr. charge. We thus see that a drop of 3in. results from the reduction of 5grs. in the powder charge—that being the distance the line *c d* is below *a b;* and a further drop of 4in. results from reducing the charge another 5grs., as shown by the distance the line *e f* is below *c d;* or a total drop of 7in. on the target with a reduction in the powder charge of 10grs. Of course it is very unlikely that such errors in the quantity of powder used would occur undesignedly; but, we can see in what direction and to what extent similar though smaller variations in our powder charge would lead us. I now come to another and most remarkable feature manifested by the rifle in connection with this experiment. These respective charges were tested from this rifle for muzzle speed, or its usual equivalent "observed velocity," at 105ft. from the muzzle of the rifle with the following results, as shown by the chronograph:

| 115 grain Charge. | | 110 grain Charge. | | 105 grain Charge. | |
|---|---|---|---|---|---|
| 1810 | Mean 1818 ft. per sec. | 1790 | Mean 1790·8 ft. per sec. | 1765 | Mean 1747 ft. per sec. |
| 1810 | | 1794 | | 1755 | |
| 1820 | | 1790 | | 1765 | |
| 1820 | | 1788 | | 1735 | |
| 1830 | | 1792 | | 1715 | |

or a difference between the two highest charges of 28ft. per second nearly, and a difference of 43ft. between the medium charge and the lowest, making a total of 71ft. per second in all.

Now, according to the tables on page 143, *et seq.*, which have been most carefully elaborated from authentic data, the drop of the bullet due to the gross reduction of bullet speed would be certainly less than 1in. upon the target; but, as we find it so much more, we must seek for the additional cause. We find, in firing these respective charges, a noticeable reduction of the recoil blow with the smallest charge; and it is very probable that, with less recoil, there is less "jump" of the muzzle, particularly as the bullet weight remains the same in all cases; therefore we must expect the bullet, deprived as it is of the upward direction given it by the superior "jump" of the heavier charge, to strike lower on the target when fired with the smaller one, which is the case. No doubt more extended experiments are wanted to fully establish this peculiarity attending rifles of moderate weight fired with heavy powder charges. Such investigations when carried out will most probably result in defining the influence exerted by "jump" under definite conditions—a point at present but vaguely understood; but I fully believe that my illustration of its effect in such a case as the one stated, and which I have endeavoured to describe to my readers, will be found to be substantially correct.

### WIND INFLUENCE AT 100 YARDS RANGE.

The influence of wind on the flight of Express rifle bullets is much more marked than might be expected, considering the short ranges at which they are fired. It is indicated on pp. 73 and 74 of this volume what effect a "head" or "rear" wind might be expected to have on a bullet moving under certain conditions. It will be found, however, in practice, that the variations in position, or "up and down," upon the target due to the action of wind with Express bullets, will be rather more than we might expect from the illustration there given; but when we consider the lightness of these bullets, together with the amount of air-resistance set up by their rapid flight, and their consequent loss of speed in traversing comparatively short distances, we shall be prepared for an occasional amount of "drop" of some two or three inches, due to the action of a gust of wind from the front upon the bullet. With side winds the effect is more marked, as it is not unfrequent, in firing on a gusty day, with the wind blowing in a direction square across the line of fire, to get a shot occasionally blown away to leeward some 4in. or 5in. from the mean centre of the group, and this, too, when the firer and his rifle occupy a sheltered spot. When we consider the superior surface offered by a conical bullet to the action of a side wind, as compared with the smaller end-on surface of the same bullet, the increased lateral deviation from this cause will be readily understood. Consequently, we must never expect a fine group of shots from a rifle on a gusty day, unless, indeed, we are lucky in catching the intermittent wind variations, as these cause the great trouble. If the wind blows strongly, but steadily, the group will be more or less away from the point of aim, but will more fairly represent the capabilities of the weapon.

### OPINIONS UPON "JUMP" AND "FLIP."

Before quite leaving the question as to the amount of influence exerted upon the bullet by the movement of the rifle at or about the time of firing, and the consequent effect upon what should be the position of the shot upon the target as compared with the point of aim, I wish to lay before my readers the following remarks from Mr. Osborne, which give rather a different explanation of one portion of the performance of the rifle under the above circumstances. They are in reply to some queries addressed to him by me in relation to the matters treated upon by Mr. Metford at pp. 224 *et seq.*:

> I cannot quite agree with the solution offered by Mr. Metford as to the reason of what may be called the false zero in the sighting of rifles.
>
> That some slight, very slight, "buckling" of a duly proportioned rifle barrel *may* take place during the explosion of the charge is probable, but that it occurs to any marked extent is not likely. Had the experiment quoted been continued, and the "grip" of the stock been either considerably reduced in diameter, or other-

wise weakened—for instance, by a saw cut partially through it—the peculiar action of the rifle during firing would have been much more marked, thus leading to the conclusion that the "flip" or drooping of the muzzle observed is much more due to the springing of the stock than to anything occurring to the barrel. No one having a large experience with rifles, which from their character as sporting weapons are apt to be pushed unduly in the matter of strength and consequent rigidity of stock attachment, while their barrels are more than usually stout and heavy, could arrive at any other conclusion.

It is just possible that with a long rifle barrel unduly light forward there *may* be, if rifled upon Mr. Metford's system of a gaining twist, a tendency to "buckle," on account of some extra strain put upon it towards the muzzle by the resistance of the bullet to the change of pitch which becomes most marked toward that portion of the barrel.

It will, of course, be easily seen that a rather slightly proportioned rifle barrel, so constructed as to have its wall of metal rather thicker (or harder) on one side of the bore than the other, might, if the weaker side happened to be in a certain position with regard to the mass of the rifle generally, be so acted upon by the force of the explosion as to amplify the peculiar effects that are the result of muzzle droop.

Other causes may operate in this direction more or less; for instance, you will remember the complaints against the early Lefaucheux B.L. shot guns, whose breech actions at that early period were so slight in scantling, and so loosely fitted that at every shot the muzzle drooped perceptibly.

With regard to the question of lubrication, I believe you will find that the felt waddings used in the Metford M.B.L. rifle cartridges are saturated with bees-wax, or some similar substance. Probably, with the small powder charge used in this rifle, the slight lubricative effect of such waddings so prepared is sufficient, at least *while the interior of the bore remains smooth and in good condition.*

That such waddings would give the *best* results in rifles carrying heavy powder charges with the bore surface damaged or rust-stained from the heavy wear and tear a sporting rifle is almost sure to incur, has not yet been demonstrated, to my knowledge.

As to what is to be considered "military" or not in such a matter, is not to be dogmatically laid down by any one individual, or even by one party holding certain views. It is no long time since the rifle itself was stigmatised as "not military," and in their several turns every improvement it has since received has met with the same adverse criticism. I remain, yours faithfully,

FRANK OSBORNE.

Thus it will be seen that as far as the "flip" or drop of the muzzle peculiarity goes, one authority refers it to an elastic motion of the barrel, while another considers that the stock takes the greater share in the matter, and it certainly appears to me more likely that the wooden portion of the structure should, shaped as it is, be more affected by the blow of the discharge than a stout steel tube or pair of tubes attached as in a double rifle. At all events, as far as I am concerned, the question remains unsettled.

### METHOD OF TESTING TRAJECTORY.

Having now discussed nearly all the points of any importance connected with the shooting of an Express rifle, and noticed the chief causes of errors in the results thereby obtained, I will proceed to consider an easily applied mode of ascertaining the trajectories of various kinds of rifles and ammunition at sporting ranges, which has been carried through by Mr. Osborne. This can be arrived at, according to his experiments, so that any sportsman can adopt his plan for himself, and obtain such sufficiently accurate results as to enable him to thoroughly understand the capabilities of his weapon, and the suitability of its sighting adjustment to the purposes for which he may require to use the weapon. The plan I pursued in obtaining a record of trajectories at the late *Field* trials, as set forth on pages 176, 177, and also in Chap. X., is probably, taken altogether, the most thorough mode of obtaining information on this very interesting subject possible, but it is unfortunately a method both troublesome and costly; whereas the plan Mr. Osborne describes is exceedingly simple, and though probably not so rigidly accurate in its results as the former more complete method of experiment, has this merit, that the errors that may occur in carrying it out (if any) are precisely of the kind and degree that are likely to happen when firing at game, and therefore, if possible, should be legitimately taken into account. Mr. Osborne thus describes his plan:

> The process can be carried out in two different ways, precisely identical in principle and results. Given a target, three distances are selected, say 50, 100, and 150 yards, and a series of shots are then fired from each distance at a bullseye that may be gradually enlarged in diameter so as to have the same aiming value at each respective range, care being taken that with each enlargement the lower edge of the bullseye (the actual point of aim) remain undisturbed. If these shots be fired *carefully* (a rest being used), and with exactly the same sighting with every shot, the vertical disagreement between the centres of the groups obtained at each distance will exhibit the trajectory of the weapon in a manner to be easily understood, and in full accordance with the sportsman's requirements. It is well to have the target and firing points arranged so as to be fairly upon the same level. The weak point in this plan is no doubt to be found in the difficulty there exists in aiming exactly alike at the different ranges, but this is precisely the difficulty the sportsman has to cope with in using his rifle in the field.
>
> The use of aperture sights instead of those of the usual sporting pattern would tend to much reduce the amount of error arising from this difficulty, though I have carried out a series of experiments upon this subject with such sights attached to Express rifles, resulting in no *material* differences from similar experiments in which the ordinary sights were used.
>
> The other mode of testing this matter is simply a modification of the above, that is, the shooting rest remains fixed and the target a sheet of cardboard affixed to a frame that can be placed in the ground is in succession stationed at the distances from the firer above mentioned. I give diagrams of the shooting of various kinds of sporting rifles when tested in the manner and for the purpose above described; from these it will be seen that some combinations of rifles and cartridges hitherto reputed to be of some

considerable value for sporting purposes, are, in the matter of flatness of trajectory (at least from beyond 100 yards), not quite all that may be desired ; in others the degree of excellence obtained in this respect is such as to exceed what we might be prepared to expect from theoretical conclusions only, and in one or two instances to some extent justifying the gunmaker's boast that he can produce a rifle that is almost *practically* "point blank" up to 150 yards range—though, as a matter of fact, this phrase must be entirely sunk in speaking of rifle matters, conveying as it does the falsest of false impressions.

It should be noted in considering the following diagrams that the grouping value of the rifle is not what is intended to be shown—that feature in finely shooting rifles being sufficiently shown in your account of the *Field* rifle trials; indeed, in all cases, only one barrel of a double rifle has been fired, the object being to avoid needlessly complicating the groups obtained. It should also be understood that in no case has the aim been varied from "fine" at the shorter to "full" at the longer distances more than is perhaps unavoidable in such a series of shots at varying ranges. On observation it will be at once seen that such a variation would reduce the "up and down" of the rifle materially.

### TRAJECTORY OF 12-BORE RIFLE.

The first rifle I shall take into consideration is one of 12-gauge, the long-standing favourite weapon of Forsyth and his contemporaries in Indian sport, though, instead of going back to his small charges of 4drs., or thereabouts, of powder, as used in the then muzzle-loaders, we can now venture to use 7drs. in our breechloader without fear of breaking down our rifle with fouling, or materially inconveniencing the firer from recoil, the rifle being of sufficient weight as usually made to practically absorb most of the blow from such a charge. The spherical ball is retained for reasons before stated, therefore we have a double 12-bore rifle weighing about 12½lb., with 26in. barrels, firing 7drs. of powder and a spherical-ball of about 585grs. in weight, this being delivered at a muzzle speed of about 1580ft. per second. The annexed diagram shows the results obtained from firing a series of five shots (from the left barrel of the rifle only) at the respective distances of 50, 100, and 150 yards, with the same sighting and point of aim in each case as near as may be. The line *a b* passes through the centre of the 50 yards group, *c d* cutting that of the 100 yards group, the drop of bullet, as shown upon the target between these ranges, being but 2½in. or thereabout. On firing at the 150 yards range, we find that the line *e f*, crossing the centre of group obtained at this distance, is no less than 14in. below the line *c d*, or a total drop of bullet between 50 and 150 yards of more than 16in. The results obtained at the shorter ranges are such as

3IN. SQUARES.

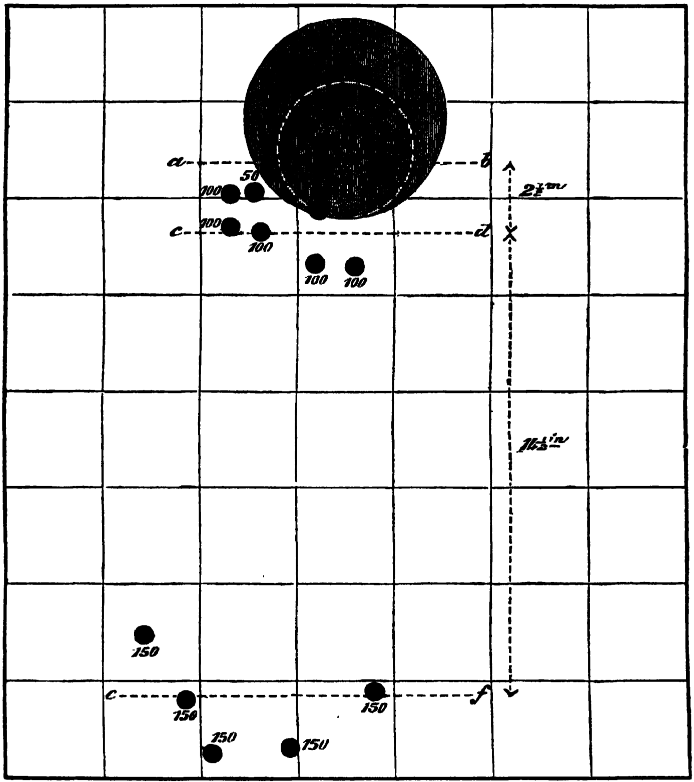

FIG. 111. DIAGRAM OF 12-BORE DOUBLE RIFLE FIRED AT THREE DISTANCES.

might be expected from the table given at p. 184, but the great drop in the next 50 yards in consequence of the rapid loss of speed from air resistance upon such a bullet as the one used may rather surprise some of your readers.

It will be sufficiently obvious that such a rifle and its ammunition as that under our notice, though powerful and effective as it should be from the weight of the arm and the amount of powder charge employed, and sufficiently flat in its trajectory within the 100 yards range, is yet largely discounted in its usefulness for general heavy game shooting by the fact of its requiring an extra sight leaf for every thirty or forty yards range beyond that distance.

3IN. SQUARES.

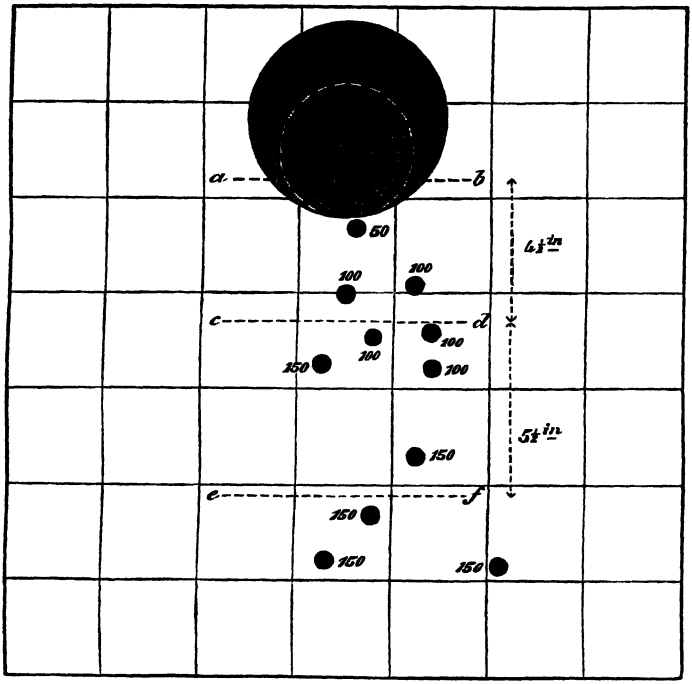

FIG. 112. DIAGRAM OF ·577 EXPRESS RIFLE FIRED AT THREE DISTANCES.

## TRAJECTORY OF ·577 EXPRESS RIFLE.

The next rifle to be considered is a ·577 Express, so called, of about 10¾lb. weight, 27in. barrels, firing a charge of 160grs. of powder, and a 520gr. bullet at a muzzle speed of about 1670ft. per second. The above diagram exhibits the shooting of this rifle under similar conditions to those previously described; but we here find a rather different state of things, more nearly approaching what we require in an Express rifle, but still by no means attaining our ideal of what that combination of rifle and ammunition should be. The difference between the line *a b* at 50 yards and that (*c d*) at 100 yards shows a drop of more than 4in., while a farther drop of over 5in. occurs between 100 and 150 yards, giving a total drop of about 10in. in the entire distance. This shows conclusively that, however *powerful* a tool the ·577 may be, it only possesses the true Express qualification in the matter of trajectory to a partial extent, though, if the method of aiming "fine" at the short range, and "full" at the longer, be adopted and *mastered,* but little practical difficulty need be experienced by the sportsman in this particular matter of using the same sight for all distances within 150 yards, showing a decided advance upon the 12-bore in this respect, besides giving us a much more easily portable arm of equal if not superior, power. On comparing this illustration of the trajectory of a ·577 rifle with the examples given in the *Field* trials, some little discrepancy may be found to exist between them; but, if allowances be made for the variation in load, and probably also in other details, the two statements will be found capable of reconciliation.

## TRAJECTORY OF ·500 EXPRESS RIFLE.

We now come to an example of a sporting rifle that very fairly illustrates the remarkable advance in the development of these weapons, resulting in the production of such an arm as that we are about to consider. This rifle is a double ·500 Express, of about 9¾lb. weight, 28in. barrels, firing 130gr. of powder, and a 350gr. bullet, having a muzzle speed of about 1880ft. per second. It will be seen from the accompanying diagram that a drop of over 3in. occurs between 50 and 100 yards, and only a drop of about 1in. between the latter distance and 150 yards. This is manifestly in utter disagreement with all the laws governing the flight of projectiles, and we must seek for an explanation of the anomaly in the action of the "jump" of the rifle in firing. That this "jump" has a greater angular value upon the target when the rifle is fired from a longer range is obvious, and therefore at, or between, the shorter ranges its effects are not so striking as upon the relative position of the group fired from the 150 yards, where, as will be seen, the "jump" has very nearly neutralised the drop of the bullet due to air resistance and gravity pull; thus, what is called the long "point blank" of the Express combination of rifle and ammunition is largely due to the effect of the "jump" upon the rifle in firing, giving an increased momentary amount of angle of elevation, in addition to the permanent angle of the sight adjustment. The entire "up and down" of this rifle from the centres of the respective groups at 50 and 150 yards is but 4½in., thus giving the sportsman a command of the vital portions of any ordinary-sized animal's frame from any point within the longer range—and satisfying every condition of sport likely to arise in the pursuit of heavy and dangerous game, especially when we consider the severe shock and lacerating effect of the bullet used. It should also be noticed that these advantages are combined with those of moderate recoil, and an easily portable weapon.

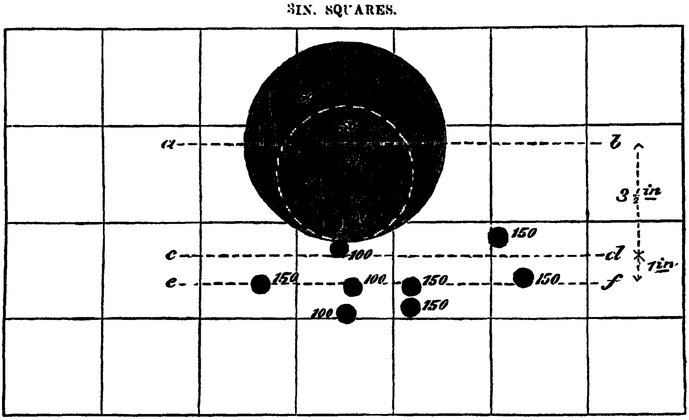

FIG. 113. DIAGRAM OF ·500 EXPRESS RIFLE FIRED AT THREE DISTANCES.

## TRAJECTORY OF ·450 EXPRESS RIFLE.

One other example of a still higher degree of development of the Express rifle fired under the same conditions as those already discussed, is given on the diagram herewith.

The rifle is a double ·450 "Magnum" Express of 9½lb. weight, 26in. barrels, firing 150grs. of powder, and a 270gr. bullet, with a muzzle speed of 2000ft. per second and upwards.

It will be noticed that the lines crossing the centres of each group are in an up and down of less than 3in., and that the entire fifteen shots are in 6in. of vertical measurement; it will also be seen that the line *e f*, indicating the centre of the 150 yards group, is actually higher or nearer that of the 50 yards group than is the line *c d* belonging to the shots fired at 100 yards range. Of course this abnormal state of things can only be attributed to the peculiar effect of the "jump" action of the rifle in firing, and even experienced rifle shots may be excused for having overlooked the influence this action of the rifle has upon the vertical deviation of its fire at various ranges with the same sighting used at each.

3IN. SQUARES.

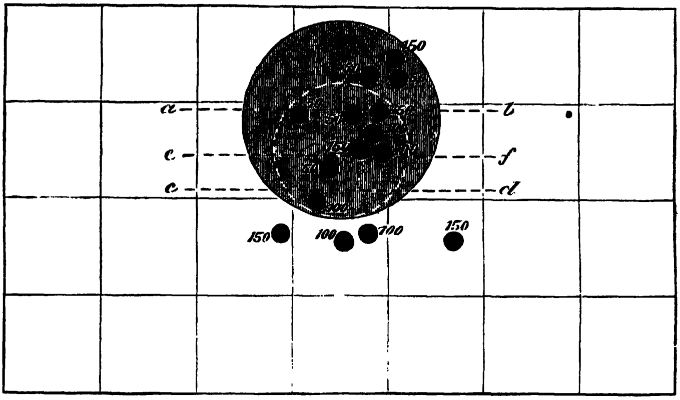

FIG. 114. DIAGRAM OF ·450 "MAGNUM" EXPRESS RIFLE FIRED AT THREE DISTANCES.

## TRAJECTORY OF MARTINI-HENRY SPORTING RIFLE.

As an illustration of the manner in which a rifle and its ammunition of small calibre, constructed upon other than Express lines, comes out when treated for diagram upon this plan, I give the results obtained from firing a single sporting Martini-Henry rifle of 8¾lb. weight, 28in. barrel, using the Government pattern ·577-·450 service cartridges, containing 85grs. powder, and 480gr. bullet, with a muzzle speed of about 1240ft. per second.

It will be seen that, at 50 and 100 yards, there is no serious amount of drop or vertical deviation of bullet other than exists in most sporting rifles, but on firing at 150 yards, we find a serious drop really requiring an additional sight leaf to render the rifle useful for sporting purposes when fired from this range. As in the previous diagrams, the line *a b*, belonging to the 50 yards group, is here seen to be 3in. above the line *c d* of the 100 yards group, but the line *e f* of the 150 yards group is nearly 12in. below the former, showing a total drop of nearly 15in. in all.

The contrast between the two diagrams immediately preceding, and the one under consideration, affords conclusive evidence of the great value of the modern Express system for ordinary sporting requirements.

Having now as far as my space permits explained and illustrated, by examples of the leading types of sporting rifles, this method of ascertaining their trajectory values, it will be necessary for me to state that the foregoing diagrams must not be expected to be *literally* repeated in the firing of any similar rifles by the sportsman. On the contrary, each rifle will be found more or less to have an individuality of its own in this matter of "up and down" (and also in other points) as compared with the results shown in the above diagrams, though these may be taken as representing about, or perhaps rather above, the fair average in the matter of trajectory of each system of rifle and ammunition investigated.

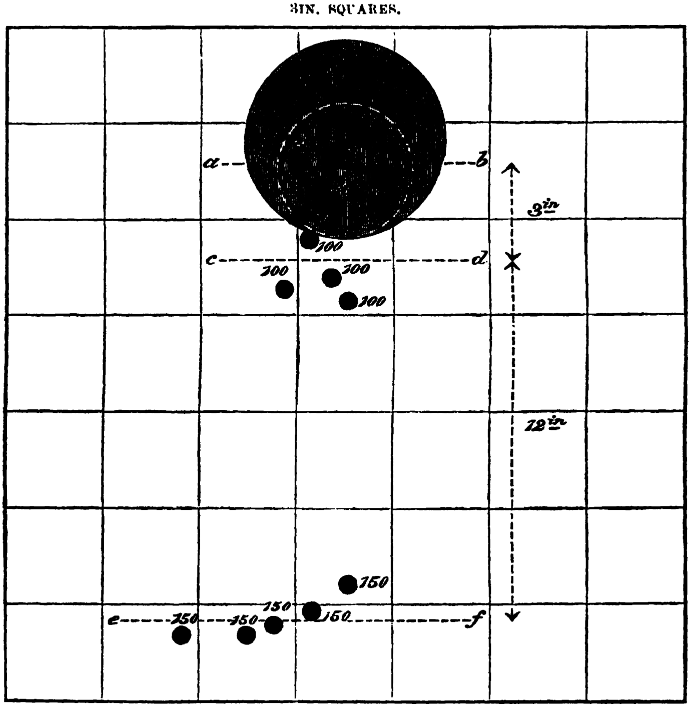

FIG. 115. DIAGRAM OF RIFLE USING THE ·577–·450 GOVERNMENT M.H. CARTRIDGE FIRED AT THREE DISTANCES.

In testing the rifle for accuracy of fire, sighting, &c., a very similar plan may be adopted to the one I have described, but of course both barrels must be fired alternately, care being taken not to injure the groups obtained by firing too rapidly.

F. Osborne.

It will be seen that the requirements of sport have led to the development of the Express rifle and its ammunition, in a manner that may be best explained and understood by treating it as a combination of the accuracy and portability of the old-fashioned rifles using light bullet and powder charge, with the smashing power of the heavier and larger calibres; but the specially prominent feature of the Express, its flat trajectory (within sporting ranges), is peculiarly its own, and results, as I have endeavoured to explain, partly from the high speed of its projectile, and partly from the effect of the "jump" upon the rifle in augmenting the angle of elevation already established and existing upon the sights of the weapon. Of course the action of "flip" or muzzle droop during the act of firing would tend to destroy or neutralise the beneficial action of the jump in this respect. However, as I have before remarked, further evidence on these interesting subjects is necessary to their full elucidation, and I shall be glad to receive and publish in the columns of the *Field*, any results of carefully conducted experiments that may be transmitted to me for that purpose. Should Mr. Osborne's experiments be repeated by any of my readers who desire absolute accuracy in ascertaining the trajectory of a rifle, I would suggest that the front sight should be raised, so as to make the line of aim parallel with the axis of the barrel. The difference of angle does not practically affect the result to any appreciable extent, but theoretically it may be objected to.

Considerations of space now compel me to bring this chapter to a close, though the subject is by no means exhausted, but I trust it has been so sufficiently treated as to give my readers some little information upon the very interesting points we have had under consideration. They will perceive that the questions involved in the construction of a first-rate double sporting rifle are of a very complex character, and demand, for their successful treatment, the possession of a high order of skill and considerable experience on the part of the rifle maker; and that, farther, it is not in the nature of things for us to expect that such a combination of science and art as is embodied in a really fine rifle should be available at a low price; and in this matter a few pounds judiciously laid out in what appears to be the extra charges of a good maker is most certainly money well spent.

# CHAPTER X.

## PUBLIC TRIAL OF SPORTING RIFLES.

OBJECTS OF TRIAL—REPORT OF TRIAL—ROOK RIFLES—EXPRESS RIFLES—LARGE BORE RIFLES—TABLES OF DIAGRAMS.

In order to establish a standard of the performances made by the several kinds of rifle used in sport, I instituted a public trial at Putney, in the summer of last year, giving fully two months' notice to the gunmakers. Unfortunately I was unable to get the ground for the trial later than October, and as a consequence, several leading firms, being engaged in preparing for the forthcoming season, were precluded from competing. Nevertheless, I was fortunate in obtaining an entry for every class from Messrs. Holland, who are admittedly in the A1 class, and, no pains being spared either by Mr. Henry Holland or his assistant, Mr. Froome, not only did they win every prize, but the performance of each rifle may be accepted as of the very highest character—and in fact this position has as far as I know never been disputed. In addition to the attainment of a standard, I was also anxious to ascertain, through an actual demonstration by means of screens, how far the Boulengé chronograph is to be relied on as a measure of trajectory; and, lastly, I was desirous of arriving at the actual distance up to which a "full and fine" sight will cover a vital part in an animal of the size of a deer, as *ex. gr.*, the heart or brain. This was clearly shewn to reach 150 yards, beyond which I was not able to test any rifle; but with the

Express rifle giving 1750ft. muzzle velocity, the highest point of the trajectory is little over 4in. on the average, and this is well covered by a "full and fine" sight.

It may, therefore, be alleged, without fear of contradiction, that I have, by means of the trial to be presently described, ascertained, 1st, the highest standard of the performance of the several sporting rifles in general use; 2ndly, that the Boulengé chronograph, giving the muzzle velocity of any rifle, will enable any person conversant with figures, by means of Bashforth's tables, to ascertain the trajectory of that rifle, as has been explained by my friend "T," in Book IV.; and 3rdly, that an Express rifle may be used with the same sight, "full and fine," up to 150 yards. I shall now proceed to give the report of the trial as published in the *Field* of Oct. 6 and subsequent issue, 1883.

## REPORT OF THE RIFLE TRIAL OF 1883.

"It is a source of great gratification to us that the above trial (held at Putney, Oct. 1, 3, and 4), has been brought off without the slightest drawback, and with the most satisfactory results. In order to allow of the use of screens with the view of demonstrating to the eye of the spectator the trajectories of Express rifles, we were compelled to select a range which could be well fenced in from the wind, and at the same time so near our own residence as to enable us to level the screens with perfect accuracy. For this purpose we were luckily able to obtain the use of a piece of ground at Putney; but the annoyance to the inhabitants was so great, that we stopped before reaching the big rifles of 12, 10, 8, and 4-bore, and postponed their trial for a few days, with the view of shooting them at some one of the open ranges near London. The weather, on the whole, was favourable, and specially so on Monday and Tuesday; but on Wednesday there was a steady light rain all day, and on

Thursday a strong wind from the left front, against which even 9ft. fences were no great protection; but, the only rifles then tested being ·577 Expresses, the high velocities and heavy balls caused the wind to have little or no effect. We were enabled to obtain the trajectories of the four winning rifles, but time did not permit us to try any more; besides which, the wind on Thursday, blowing down the range when we proposed to do this, was so high as to burst the paper unless the wires were kept up to back it, and this we found to be dangerous, one of the balls hitting a wire which was of strong steel, and being thereby deflected off the target, and of course it might possibly reach an individual outside the range. Our butt was 25ft. high, of solid bricks, faced with 3ft. of sand, boarded in front, so that no ordinary shooting was attended with danger; but in one case Mr. Adams's ammunition was defective, and three balls stripped at 50 yards, upsetting, and going a foot or two outside the carton; so that he at once withdrew the gun, as possibly unsafe at the longer ranges, saving us from the disagreeable necessity of doing so ourselves.

Messrs. Holland's rifles performed throughout most splendidly, and, though occasionally they were beaten at individual ranges, their averages were highest in each class. In one instance, indeed (Class 4), they came second at each range, but, nevertheless, came out first on the average of the three ranges.

In all the classes Messrs. Holland abstained from cleaning out from first to last. The other competitors cleaned out after each change of range, as permitted by the conditions. This speaks volumes for the excellent lubrication used by the above firm, and for their plans of rifling.

The following is the score of the several classes, calculated by Mr. B. C. Evelegh, under the inspection of the competitors, from centres selected by themselves. The mean radial deviation is given in inches and decimal parts of an inch:

## ROOK RIFLES.

Class 1, single rook rifles not exceeding 6lb. in weight, barrels not to exceed 28in. in length; ranges, 50 and 75 yards, twenty shots at each range. No trial for trajectory.

| 50 Yards. | In. | 75 Yards. | In. |
|---|---|---|---|
| Holland | ·395 | Holland | ·696 |
| Tranter | ·821 | Adams | 1·428 |
| Watson | ·914 | Tranter | 1·566 |
| Bland | ·916 | Jeffries | 1·728 |
| Adams | 1·077 | Bland | 1·905 |
| Jeffries | 1·170 | Watson | 2·034 |

| Averages for the Two Ranges. | | Order of Merit. |
|---|---|---|
| Holland | ·545 | 1 |
| Tranter | 1·193 | 2 |
| Adams | 1·253 | 3 |
| Bland | 1·410 | 4 |
| Jeffries | 1·449 | 5 |
| Watson | 1·474 | 6 |

The diagram made at 50 yards by Messrs. Holland's ·295 is the best we have ever seen made, and astonished some of the London gunmakers who were present, and who were previously sceptical as to the diagrams we have from time to time recorded in our columns. The bull was in fact cut all

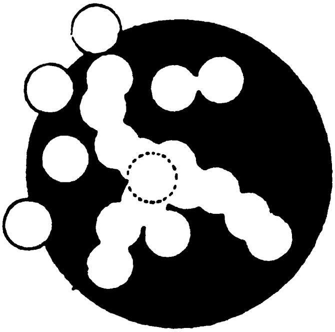

Fig. 116. Holland's Rook Rifle at 50 Yards.

to pieces in the centre, and it was difficult in several of the shots to fix the exact situation of each hole.

Their 75 yards diagram is also extremely good. All the competitors who had entered a second rifle withdrew it, not having any hope of beating Messrs. Holland's diagram.

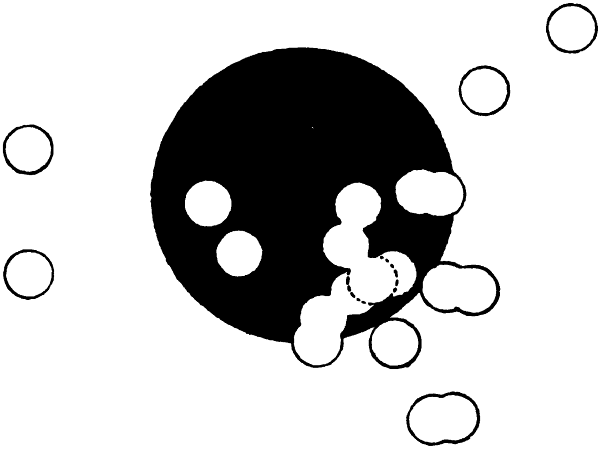

Fig. 117. Holland's Rook Rifle at 75 Yards.

EXPRESS RIFLES.

Class 2. For ·400-bore double rifles, weight not to exceed 8lb., barrels not to exceed 28in.; powder not to be less than 3drs., weight of lead not more than three times the weight of powder; ranges, 50, 100, and 150 yards.

| | 50 Yards. | 100 Yards. | 150 Yards. |
|---|---|---|---|
| Holland | 1·139 | 2·139 | 3·232 |

Average of the three ranges............ 2·183.

Here Messrs. Holland had no competitor, owing to Messrs. Bland's rifle being 1½oz. overweight, and that Mr. Watson did not appear with his. The performance was of the very highest class, the weather and light being favourable. Recoil at 50lb. pressure, 71lb.

Class 3. For double rifles of ·450-bore; weight not to exceed 9lb., barrels not more than 28in.; powder not less than 4drs., weight of lead not to exceed three times the weight of powder; ranges as in Class 2.

| | 50 yds. | Order of Merit at 50 yds. | 100 yds. | Order of Merit at 100 yds. | 150 yds. | Order of Merit at 150 yds. |
|---|---|---|---|---|---|---|
| Bland, No. 1... | 1·032 | 1 | 2·752 | 2 | 6·980 | 3 |
| Holland......... | 1·132 | 2 | 1·318 | 1 | 1·449 | 1 |
| Bland, No. 2... | 1·300 | 3 | 2·763 | 3 | 5·936 | 2 |

| Average of the Three Ranges. | | Order of Merit. |
|---|---|---|
| Holland | 1·299 | 1 |
| Bland, No. 2 | 3·333 | 2 |
| Bland, No. 1 | 3·588 | 3 |

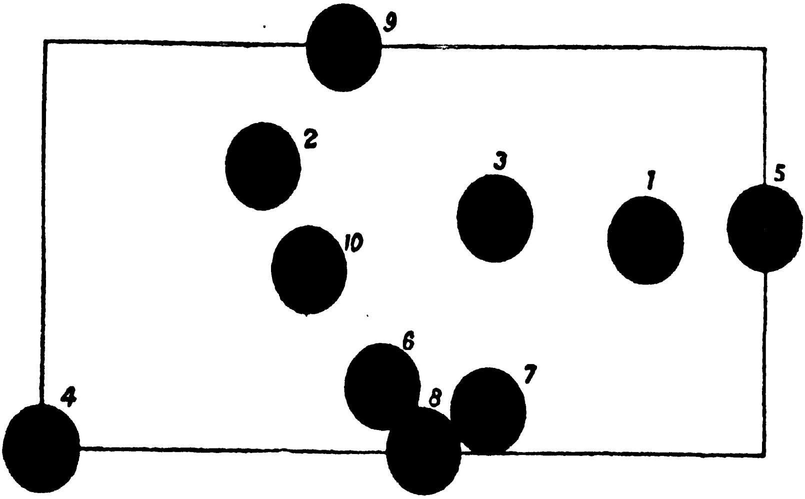

Fig. 118. Holland's ·450-Bore at 50 Yards.

In this trial Messrs. Bland's made an excellent diagram at 50 yards, but were behind at the longer ranges. Messrs. Adams's rifle was withdrawn, as above mentioned, for three wild shots. Here again Mr. Watson did not appear. The recoil of the winner was 96lb.

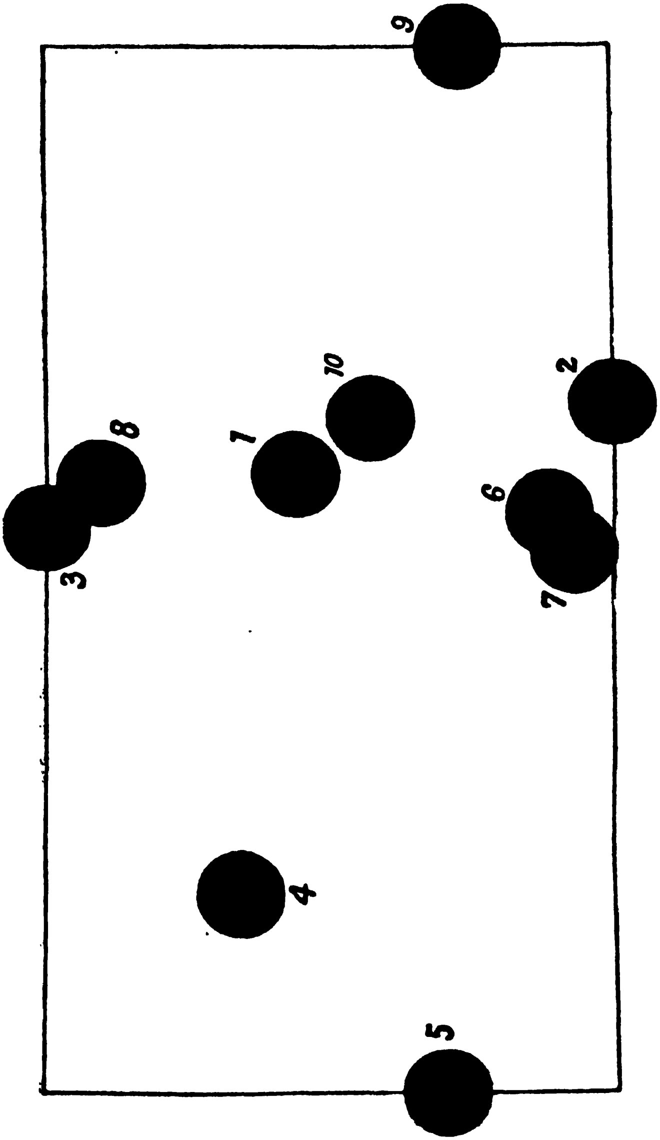

FIG. 119. HOLLAND'S ·450-BORE AT 100 YARDS.

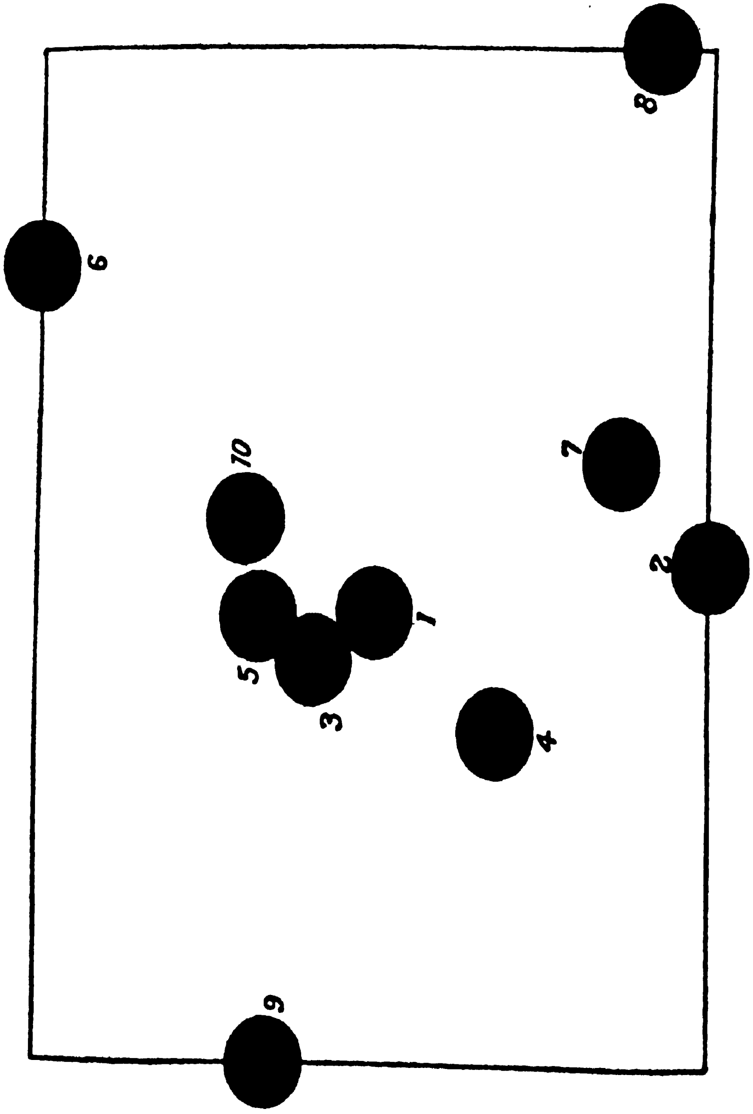

Fig. 120. Holland's ·450-Bore at 150 Yards.

Class 4, for double rifles of ·500-bore; weight not to exceed 10lb., length of barrels not to exceed 28in.; powder not less than 5drs.; lead to be not more than three and a half times the weight of powder; ranges as in Class 2.

| | 50yds. | Order of Merit at 50yds. | 100yds. | Order of Merit at 100yds. | 150yds. | Order of Merit at 150yds. |
|---|---|---|---|---|---|---|
| Jeffries ......... | 1·052 | 1 | 1·004 | 1 | 4·124 | 3 |
| Holland ......... | 1·093 | 2 | 1·164 | 2 | 2·900 | 2 |
| Adams ......... | 1·489 | 3 | 3·872 | 4 | 2·400 | 1 |
| Bland, No. 2... | 1·928 | 4 | 3·405 | 3 | 8·209 | |
| Bland, No. 1... | 1·989 | 5 | 4·127 | 5 | 5·277 | 4 |

AVERAGE OF THE THREE RANGES.

| | | Order o Merit. |
|---|---|---|
| Holland ......................... | 1·719 ......................... | 1 |
| Jeffries ......................... | 2·060 ......................... | 2 |
| Adams ......................... | 2·587 ......................... | 3 |
| Bland, No. 1 ..................... | 3·797 ......................... | 4 |
| Bland, No. 2 ..................... | 4·514 ......................... | 5 |

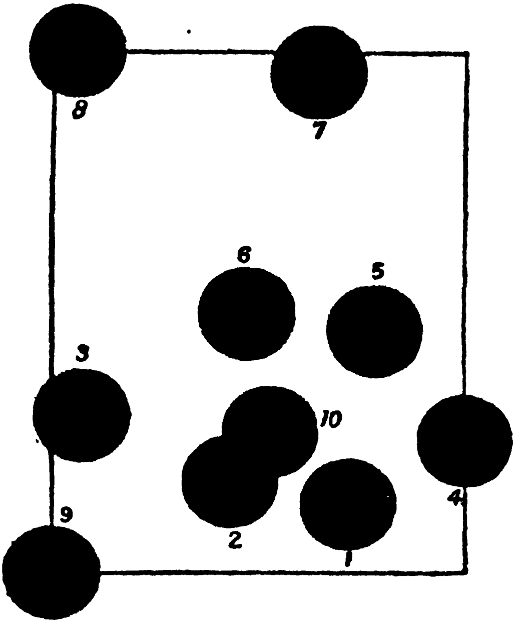

FIG. 121. JEFFRIES' ·500-BORE AT 50 YARDS.

In this class Mr. Jeffries pushed Messrs. Holland very hard, making a splendid diagram at the first two ranges, but breaking down slightly at 150 yards. Mr. Adams's second rifle was disqualified for being overweight. The recoil of the winner was 101lb.

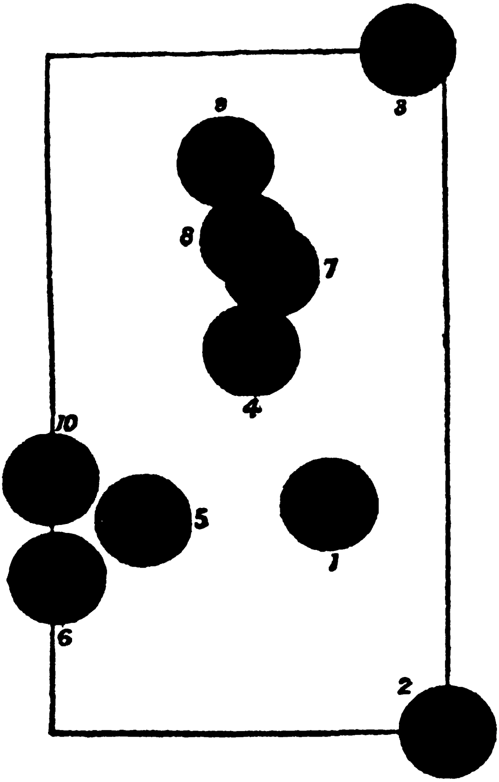

FIG. 122. JEFFRIES' ·500-BORE AT 100 YARDS.

Class 5, for double rifles of ·577-bore; weight not to exceed 12lb., length of barrels not to exceed 28in.; powder not less than 6drs ; lead not more than four times the weight of powder; to be shot at the same ranges as Class 2.

| | 50yds. | Order of Merit at 50yds. | 100yds. | Order of Merit at 100yds. | 150 yds. | Order of Merit at 150yds. |
|---|---|---|---|---|---|---|
| Adams, No. 1.. | 1·056 | 1 | 2·791 | 2 | 5·874 | 6 |
| Holland......... | 1·128 | 2 | 2·098 | 1 | 2·418 | 1 |
| Adams, No. 2.. | 1·200 | 3 | 3·131 | 4 | 3·427 | 2 |
| Bland, No. 2... | 1·594 | 4 | 4·092 | 6 | 4·521 | 4 |
| Watson ......... | 1·826 | 5 | 2·870 | 3 | 5·098 | 5 |
| Bland, No. 1... | 2·058 | 6 | 3·806 | 5 | 4·373 | 3 |

| AVERAGE OF THE THREE RANGES. | | Order of Merit. |
|---|---|---|
| Holland | 1·881 | 1 |
| Adams, No. 2 | 2·586 | 2 |
| Adams, No. 1 | 3·240 | 3 |
| Watson | 3·281 | 4 |
| Bland, No. 2 | 3·402 | 5 |
| Bland, No. 1 | 3·412 | 6 |

In this class Mr. Adams (for whom Mr. Bates, the well-known match rifle shot, performed throughout) took the lead at 50 yards, but could not sustain his position further on, and Messrs. Holland again won on the average, with a very splendid rifle, which, indeed, was the pick of their wonderful basket. Recoil, 119½lb.

We may mention that all competitors expressed their entire satisfaction with the arrangements, including the measuring machine, which was designed and made for the occasion."

"For the completion of our trial of the large bores, we were permitted by Mr. Brown, of Nunhead, to use a portion of his capital ground on Tuesday, Oct. 9, and were fortunately favoured with a remarkably fine day, without either sun, rain, or wind. As at Putney, Messrs. Holland carried all before them, winning classes 6, 7, and 8 from Messrs. Bland, who were their only competitors, and scoring first in classes 9 and 10, owing to Messrs. Bland's man, who was charged to be at Nunhead by twelve o'clock, not appearing till 1.45, when Messrs. Holland had walked over with his smooth-bore, and had got half through with his 4-bore. The latter performed wonderfully, giving perhaps the best diagram made in the whole trial; but it was unlucky for Messrs. Bland that they had no chance of shooting with their smooth-bore, as that of Messrs. Holland was by no means first-rate, the diagram being just within a foot square. We have repeatedly been told by gunmakers that a diagram six inches square may be made with this weapon; but, after trying the experiment at least twenty times, with guns from various makers, we have never seen less than nine-inch diagram; but this has resulted once or twice, and Mr. Froome, who shoots and regulates Messrs. Holland's rifles, states that he has more than once made a six-inch diagram within the last few days. Naturally, public performance seldom equals that done in private, but, making all allowance for this difference, Mr. Froome's shooting with the smooth-bore at Nunhead was such as to give Messrs. Bland a fair chance, if the trial had come off. In all the other classes, although he was occasionally beaten at 50 and 100 yards, he always had so much the best at 150 yards, that he came out the winner; and, taking the whole series of trials into consideration, his shooting has been of of the very highest order. Messrs. Holland may certainly congratulate themselves on the possession of so competent an assistant in regulating and shooting their rifles. Mr. H. Holland, who personally designed the whole of the magnificent series of rifles which were tested by us, also richly deserves the credit that attaches to their performance. We understand that the whole of them were rifled under his superintendence, and afterwards regulated and shot at his Kensal Green ground by Mr. Froome.

We append the diagrams made by his rook rifle, and also those of his ·450-bore, which, taking all the ranges, did perhaps the best. We have selected this bore for the following reasons: First, it is the only one in which we were able to test another of the same class (Messrs. Bland's) through the screens, and, secondly, because it is the same bore as that of the rifle we tested, and described in the *Field* of Feb. 24, 1883. On comparing the two diagrams, it will be seen that the one made in private is slightly the better of the two; but the 150 yards shoot at Putney is the best we have ever seen, being far superior in proportion to that made at 100 yards, as indeed was the case with almost all Messrs. Holland's rifles.

In the ·500-bore contest, as previously remarked, Mr. Froome was beaten at the 50 and 100 yards, Mr. Jeffries making a wonderful 100 yard diagram, but he fell off sadly at 150 yards, owing to the comparative lightness of his bullet, which on that account was not so true at the longer range. Mr. Holland had, however, so fixed his weights as to serve him well all through, and this was one great source of his success. The fact is, that the construction of rifles and the proper adjustment of their charges require long thought and careful trials; and it is only by the combination of theory with practice, such as is practised by the Bond-street firm, that success can be achieved.

We have not been able to measure the diagrams made at Nunhead, which requires the selection of a centre by the competitors; but there could be no doubt of the superiority of Messrs. Holland's rifles, and we have consequently awarded them the prize in each class, and they have, therefore, 'swept the board.'

We append the meteorological report of Mr. J. H. Steward (official optician to the National Rifle Association), giving the results of observations made each day at 11.30 a.m. We have added, however, the words 'light' and 'strong' after the direction of the wind.

| Date. | Barometer. | Wind. | Thermometer. | |
|---|---|---|---|---|
| | | | Dry Bulb. | Wet Bulb. |
| Monday, Oct. 1 ............ | 29·82 | S.W., light | 56 | 50 |
| Tuesday " 2 ............ | 30·08 | N., light | 52 | 46·5 |
| Wednesday, " 3 ............ | 29·65 | W., light | 49·5 | 48·5 |
| Thursday, " 4 ............ | 29·56 | N.W., strong | 52 | 49 |

We may add that the range ran from north to south, the targets being at the northern end.

The following tables have been drawn up with great care, and give all the details of the shooting from the shoulder throughout the Putney trials, with the strings calculated on the plan laid down in the programme."

## CLASS I.—ROOK RIFLES.

**SINGLE RIFLES**, not exceeding 6lb. in weight, nor 28 inches in length; ranges 50 and 75 yards; 20 shots at each range.

### *String at 50 Yards.*

Average inches.

**HOLLAND** (·295-bore; weight, 5lb. 15oz.; length, 28in.; powder, 12grs.).—·69, ·53, ·32, ·29, ·53, ·58, ·48, ·81, ·56, ·71, ·48, ·68, ·18, ·11, ·13, 0, ·11, ·17, ·25, ·30; total, 7·91 inches ............... ·395

**TRANTER** (·300-bore; weight, 5lb. 15oz.; length, 27¾in.; powder, 17grs.).—·94, ·78, ·78, ·76, 1·65, 1·77, ·65, ·13, ·30, ·54, ·80, ·60, ·60, ·67, ·92, 1·11, 0, 1·02, 1·52, ·88; total, 16·42 inches ......... ·821

**WATSON** (·300-bore; weight, 5lb. 15½oz.; length, 27¾in.; powder, 17grs.).—·26, ·20, ·55, 1·46, 1·68, 1·05, ·85, 0, ·32, 1·03, ·38, 1·30, 1·71, 1·77, 2·57, ·29, ·53, ·84, 1·00, ·49; total, 18·28 inches ............... ·914

**BLAND** (·360-bore; weight, 5lb. 12oz.; length, 27½in.; powder, 14grs.).—1·30, ·82, ·70, ·26, ·48, 1·65, 1·20, 1·08, ·58, 1·15, ·82, 1·01, 1·45, 0, ·23, 1·37, ·81, 1·50, ·23, 1·65; total, 18·32 inches ·916

**ADAMS** (·360-bore; weight, 4lb. 10oz.; length, 25½in.; powder, 14grs.).—·60, ·50, 1·58, 1·46, 1·57, 1·04, ·99, ·81, ·55, ·86, 1·14, 1·11, ·87, ·81, 1·32, 1·40, 1·26, ·83, 1·45, 1·40; total, 21·55 inches ............... 1·077

**JEFFRIES** (·300-bore; weight, 5lb. 12oz.; length, 27½in.; powder, 12grs.).—·14, 1·38, 1·86, 1·41, 1·14, 1·49, 2·05, ·40, 2·01, 1·09, 1·00, ·37, ·48, 1·99, 1·31, 1·00, 1·51, ·80, 1·24, ·74; total, 23·41 inches ............... 1·170

### *String at 75 Yards.*

**HOLLAND.**—1·59, 1·07, ·51, ·47, ·92, ·73, 2·01, 1·85, ·39, ·48, ·40, ·83, ·88, ·50, ·38, ·38, ·10, ·05, ·16, ·22; total, 13·92 inches............ ·696

**ADAMS.**—·52, ·74, 2·56, ·98, 1·66, ·73, 1·84, ·26, 1·50, 1·35, 2·62, ·38, 2·40, ·48, ·36, 1·99, 1·40, 2·47, 1·69, 2·64; total, 28·57 inches ... 1·428

**TRANTER.**—1·89, 1·32, 3·03, 2·93, 1·49, 1·77, 1·10, 1·50, 1·23, 1·70, 1·51, 3·04, 2·16, 1·80, ·55, ·38, 1·13, 1·25, 1·54, 0; total, 31·32 inches ............... 1·566

**JEFFRIES.**—2·63, 1·36, 1·50, 2·90, ·64, 1·50, 1·70, 1·40, 1·42, 1·51, 1·81, 1·95, 1·25, 1·22, 2·89, 1·10, 1·34, 1·17, 2·87, 2·40; total, 34·56 inches ............... 1·728

**BLAND.**—·72, ·76, 1·53, 3·13, ·79, 3·30, 3·29, 2·30, 2·71, 2·30, 2·24, ·84, ·78, ·71, 2·09, 1·00, 2·48, 1·76, 2·08, 3·30; total, 38·11 inches ............... 1·905

**WATSON.**—·55, 1·89, 5·54, 3·49, 1·90, 3·64, 3·65, 1·78, 2·23, 0, ·68, 1·74, 2·32, 1·89, 2·08, ·83, 1·34, ·98, 1·59, 2·57; total, 40·69 inches ............... 2·034

### ORDER OF MERIT.

| General position. | Position at respective ranges. | Makers. | Average of the two ranges. |
|---|---|---|---|
| 1 | 1, 1 | Holland | ·545 |
| 2 | 2, 3 | Tranter | 1·193 |
| 3 | 5, 2 | Adams | 1·253 |
| 4 | 4, 5 | Bland | 1·410 |
| 5 | 6, 4 | Jeffries | 1·449 |
| 6 | 3, 6 | Watson | 1·474 |

## EXPRESS RIFLES.

### CLASS II.—·400-BORE.

**DOUBLE RIFLES**, not exceeding 8lb. in weight, nor more than 28 inches in length; powder not less than 3drs.; weight of lead not more than three times the weight of powder; ranges, 50, 100, and 150 yards; ten shots at each range.

*String at* 50 *Yards.*

Average inches.

**HOLLAND** (weight, 7lb. 14oz.; length, 26 inches; 3drs. powder and 219grs. bullet, or proportion of 1 : 2·66; recoil, 71lb.; shot on Monday evening, in a good light, with no wind).—Right barrel, 1·29, 1·15, 1·15, ·14, 1·66; left barrel, 2·28, 1·20, 1·17, 1·21, ·14; total, 11·39 inches ........................................ 1·139

100 *Yards.*

Right barrel, 1·21, ·96, 2·04, 1·17, 2·08; left barrel, 4·00, 2·57, 2·82, 1·24, 3·70; total, 21·79 inches.................................. 2·179

150 *Yards.*

Right barrel, 4·97, 1·77, 1·69, 4·54, 5·59; left barrel, 2·38, 2·36, 1·86, 1·81, 5·35; total, 32·32 inches.................................. 3·232

Average of the three ranges .......................... 2·183

**BLAND.**—Rifle not tried, being 1½oz. over weight.

### CLASS III.—·450-BORE.

**DOUBLE RIFLES**, not exceeding 9lb. in weight, nor more than 28 inches in length; powder not less than 4drs.; weight of lead not more than three times the weight of powder; ranges 50, 100, 150 yards; ten shots at each range.

*String at* 50 *Yards.*

Average inches.

**BLAND**, No. 1 (weight, 8lb. 13½oz.; length, 28in.; 110grs. powder and 300grs. bullet, or proportion of 1 : 2·72; shot at 11 o'clock on Tuesday).—Right barrel, ·51, ·84, ·85, ·49, 1·55; left barrel, ·58, ·97, 1·20, 1·98, 1·35; total, 10·32 inches........................ 1·032

**Holland** (weight, 8lb. 4oz.; length, 26in.; 110grs. powder and 328grs. bullet, or proportion of 1 : 2·98; recoil, 96lb.; shot on Tuesday afternoon).—Right barrel, 1·64, ·78, 2·34, ·92, 1·17; left barrel, ·76, 2·06, ·46, ·90, ·29; total, 11·32 inches............ 1·132

**Bland**, No. 2 (weight, 9lb.; length, 28in.; 110grs. powder and 300grs. bullet, or proportion of 1 : 2·72; recoil, 89lb.; shot on Tuesday afternoon).—Right barrel, 2·32, 1·49, 1·17, ·98, 1·09; left barrel, 1·29, ·85, 1·48, ·95, 1·38; total, 13 inches ............ 1·300

### *String at* 100 *Yards.*

**Holland.**—Right barrel, ·44, 1·78, 2·17, ·93, 2·13; left barrel, 1·08, 2·29, ·74, 1·41, ·21; total, 13·18 inches........................ 1·318

**Bland**, No. 1.—Right barrel, 5·49, 2·11, 3·32, 2·14, 3·27; left barrel, ·38, 2·39, 1·95, 3·28, 3·19; total, 27·52 inches ............ 2·752

**Bland**, No. 2.—Right barrel, 5·15, 3·49, 1·84, 3·54, 2·32; left barrel, 2·88, 1·89, 2·53, 2·8, 1·19; total, 27·63 inches ............ 2·763

### *String at* 150 *Yards.*

**Holland.**—Right barrel, ·38, ·27, ·28, 1·88, 2·17; left barrel, 2·25, 1·21, 2·21, 3·33, ·51; total, 14·49 inches.............................. 1·449

**Bland**, No. 2.—Right barrel, 6·16, 4·52, 10·67, 6·20, 3·18; left barrel, 4·94, 10·27, 6·06, 4·43, 2·93; total, 59·36 inches ......... 5·936

**Bland**, No. 1.—Right barrel, 6·46, 16·51, 6·27, 6·43, 5·54; left barrel, 11·3, 2·4, 2·32, 6·47, 6·10; total, 69·80 inches ............ 6·980

### ORDER OF MERIT.

| General Position. | Position at respective ranges. | Makers. | Average of the three ranges. |
|---|---|---|---|
| 1 | 2, 1, 1 | Holland | 1·299 |
| 2 | 1, 2, 3 | Bland, No. 1.. | 3·333 |
| 3 | 3, 3, 2 | „ No. 3.. | 3·588 |

### CLASS IV.—·500-BORE.

**Double Rifles**, not exceeding 10lb. in weight, nor more than 28 inches in length; powder not less than 5drs.; lead not more than 3½ times the weight of powder; ranges at 50, 100, and 150 yards; ten shots at each range.

### *String at* 50 *Yards.*

Average inches.

**Jeffries** (weight, 8lb. 4½oz.; length, 28in.; 138grs. powder and 340grs. bullet, or proportion of 1 : 2·64; shot on Wednesday morning).—Right barrel, ·52, 1·79, 1·10, ·54, 1·17; left barrel, 1·80, ·16, 1·48, ·69, 1·27; total, 10·52 inches....................... 1·052

**Holland** (weight, 9lb. 1oz.; length, 28in.; 138grs. powder and 435grs. bullet, or proportion of 1 : 3·17; recoil, 101lb.; shot on Wednesday morning).—Right barrel, ·86, 1·10, 1·25, 1·39, ·74; left barrel, ·98, 1·04, 2·00, ·75, ·82 total, 10·93 inches ......... 1·093

**Adams** (weight, 9lb. 9½oz.; length, 28in.; 138grs. powder and 328grs. bullet, or proportion of 1:2·38; shot on Tuesday evening).—Right barrel, 99, 1·89, 1·66, 1·18, 1·68; left barrel, 2·03, ·83, ·51, 2·04, 2·08; total, 14·89 inches ........................ 1·489

**Bland**, No. 2 (weight, 9lb. 5¼oz.; length, 28in.; 138grs. powder and 328grs. bullet, or proportion of 1: 2·38; shot on Wednesday, at midday).—Right barrel, 2·36, 1·89, 1·42, 1·35, 2·96; left barrel, 1·39, 1·37, 1·33, 2·25, 2·96; total, 19·28 inches ........................................................ 1·928

**Bland**, No. 1 (weight, 9lb. 12oz.; length, 28in.; 138grs. powder and 328grs. bullet, or proportion of 1: 2·38; shot on Tuesday evening).—Right barrel, ·83, 1·95, ·83, 1·68, 1·31; left barrel, 1·43, 3·09, 1·23, 3·67, 3·87: total, 19·89 inches ..................... 1·989

### *String at* 100 *Yards.*

**Jeffries.**—Right barrel, 1·14, ·64, ·88, 1·44, 1·40; left barrel, ·77, 1·47, ·21, 1·49, ·60; total, 10·04 inches ............................. 1·004

**Holland.**—Right barrel, 1·51, 1·28, ·90, 2·70, 1·34; left barrel, 0, ·22, ·85, 2·17, ·67; total, 11·64 inches .......................... 1·164

**Bland**, No. 2.—Right barrel, 7·54, 5·75, 2·03, 1·84, 2·69; left barrel, 5·18, 2·55, 1·23, 2·59, 2·65; total, 34·05 inches............ 3·405

**Adams.**—Right Barrel, 4·53, 5·14, 1·82, 4·76, 2·78; left barrel, 3·75, 5·10, 5·12, 1·69, 4·03; total, 38·72 inches .................... 3·872

**Bland**, No. 1.—Right barrel, 2·72, 3·40, 7·93, 7·04, 1·04; left barrel, 1·27, 3·38, 3·36, 9·62, 1·51; total, 41·27 inches............ 4·127

### *String at* 150 *Yards.*

**Adams.**—Right barrel, 3·29, 2·69, 3·23, 1·98, 2·02; left barrel, 2·78, 1·15, ·89, 3·24, 2·73; total, 24 inches.......................... 2·400

**Holland.**—Right barrel, 1·86, 2·49, 4·95, 2·48, 1·65; left barrel, 2·97, 4·22, 3·04, 3·15, 2·19; total, 29 inches ....................... 2·900

**Jeffries.**—Right barrel, 5·00, 6·55, ·20, 2·94, 5·32; left barrel, 4·87, 1·30, 4·46, 3·95, 6·65; total, 41·24 inches..................... 4·124

**Bland**, No. 1.—Right barrel, 4·5, 9·14, 2·90, 4·55, 2·65: left barrel, 11·43, 6·38, 4·35, 4·38, 2·49; total, 52·77 inches ................. 5·277

**Bland**, No. 2.—Right barrel, 17·58, 16·20, 8·99, 1·44, 6·36; left barrel, 6·84, 1·30, 4·64, 17·34, 1·40; total, 82·09 inches ......... 8·209

### ORDER OF MERIT.

| General position. | Position at respective ranges. | Makers. | Average of the three ranges. |
|---|---|---|---|
| 1 | 2, 2, 2 | Holland | 1·719 |
| 2 | 1, 1, 3 | Jeffries | 2·060 |
| 3 | 3, 4, 1 | Adams | 2·587 |
| 4 | 5, 5, 4 | Bland, No. 1 | 3·797 |
| 5 | 4, 3, 5 | Bland, No. 2 | 4·514 |

### Class V.—·577-bore.

Double Rifles, not exceeding 12lb. in weight, and not more than 28in. in length; powder not less than 6drs.; lead not more than four times the weight of powder; ranges 50, 100, and 150 yards; ten shots at each range.

### *String at* 50 *Yards.*

Average inches.

**Adams**, No. 1 (weight, 10lb. 11oz.; length, 28in.; 164grs. powder and 507grs. bullet, or proportion of 1 : 3·09; shot on Thursday morning).—Right barrel, ·84, ·87, 1·07, 1·40, ·57; left barrel, ·96, 1·39, ·99, 1·26, 1·21; total, 10·56 inches ........................ 1·056

**Holland** (weight, 11lb. 10oz.; length, 26in.; 164grs. powder and 598grs. bullet, or proportion of 1 : 3·63; recoil, 119½lb.; shot two rounds on Wednesday evening, the rest on Thursday morning).—Right barrel, ·44, 1·20, 1·80, ·19, 1·00; left barrel, 1·29, 2·11, 1·79, ·82, ·64; total, 11·28 inches ........................ 1·128

**Adams**, No. 2 (weight, 10lb. 14oz.; length, 28in.; 164grs. powder and 507grs. bullet, or proportion of 1 : 3·09; shot two rounds on Wednesday evening, the rest on Thursday morning, one in very high wind).—Right barrel, 1·21, 1·26, ·53, ·88, 1·68; left barrel, 1·45, 1·29, ·58, 1·41, 1·71; total, 12 inches .............. 1·200

**Bland**, No. 2 (weight, 10lb. 2oz.; length, 27¾in.; 164grs. powder and 512grs. bullet, or proportion of 1 : 3·12; shot on Thursday morning).—Right barrel, 1·18, 1·25, 1·58, 1·68, 2·84; left barrel, 1·29, 1·16, 1·37, 1·75, 1·84; total, 15·94 inches ............................................................ 1·594

**Watson** (weight, 9lb. 12oz.; length, 28in.; 164grs. powder and 501grs. bullet, or proportion of 1 : 3·05; shot on Wednesday at midday).—Right barrel, 2·05, 1·36, 2·70, 0, 3·64; left barrel, 2·41, ·94, 1·85, 2·59, 1·22; total, 18·76 inches .................... 1·876

**Bland**, No. 1 (weight, 10lb. 10oz.; length, 28in.; 164grs. powder and 512grs. bullet, or proportion of 1 : 3·12; shot on Wednesday at midday).—Right barrel, 1·57, 1·00, 2·53, 1·29, 4·98; left barrel, 1·61, 1·20, 1·63, 1·38, 3·39; total, 20·58 inches........... 2·058

### *String at* 100 *Yards.*

**Holland.**—Right barrel, 0, 1·39, 1·02, 3·01, 4·05; left barrel, 1·98, 2·70, 3·24, 2·61, ·98; total, 20·98 inches...................... 2·096

**Adams**, No. 1.—Right barrel, ·38, 2·23, 1·85, 3·54, 2·15; left barrel, 4·40, 1·41, 3·09, 4·43, 4·43; total, 27·91 inches........... 2·791

**Watson.**—Right barrel, 2·09, 3·50, 1·42, 2·83, 5·67; left barrel, 0, 3·50, 3·64, 4·34, 1·71; total, 28·70 inches ....................... 2·870

**Adams**, No. 2.—Right barrel, 3·01, 1·05, 5·13, 4·85, 3·84; left barrel, 3·30, ·23, 2·54, 5·00, 2·36; total, 31·31 inches ........... 3·131

**Bland**, No. 1.—Right barrel, 5·85, 1·39, 2·08, 8·04, 1·79; left barrel, 3·39, 1·10, 2·81, 3·42, 8·19; total, 38·06 inches............ 3·806

**Bland**, No. 2.—Right barrel, 1·69, 9·03, 6·64, 3·15, 3·00; left barrel, 2·73, 1·96, 1·15, 5·70, 5·85; total, 40·92 inches............ 4·092

### *String at* 150 *Yards.*

**Holland.**—Right barrel, 4·61, 1·74, 1·33, 3·46, 4·53; left barrel, 2·95, ·33, 1·94, ·69, 2·60; total, 24·18 inches........................ 2·418

**Adams**, No. 2.—Right barrel, 2·36, 5·23, 1·75, 3·32, 4·55; left barrel, 2·37, 5·26, 2·80, 2·25, 4·38; total, 34·27 inches............ 3·427

**Bland**, No. 1.—Right barrel, 5·31, 5·24, 1·64, 5·30, 9·09; left barrel, 3·84, 4·43, 5·33, 2·16, 1·39; total, 43·73 inches............ 4·373

**Bland**, No. 2.—Right barrel, ·74, 3·85, ·80, 2·96, 3·81; left barrel, 3·85, 6·60, 6·87, 3·73, 12·00; total, 45·21 inches ......... 4·521

**Watson.**—Right barrel, 8·56, 0, ·93, 6·67, 9·46; left barrel, 7·45, 9·44, 2·73, ·57, 4·67; total, 50·98 inches.............................. 5·098

**Adams**, No. 1.—Right barrel, 3·59, 4·16, 9·05, 2·78, 7·15; left barrel, 4·71, 5·12, 5·08, 8·29, 8·81; total, 58·74 inches............ 5·874

### Order of Merit.

| General position. | Position at respective ranges. | Maker. | Average of the three ranges. |
|---|---|---|---|
| 1 | 2, 1, 1 | Holland | 1·881 |
| 2 | 3, 4, 2 | Adams, No. 2 | 2·586 |
| 3 | 1, 2, 6 | „ No. 1 | 3·240 |
| 4 | 5, 3, 5 | Watson | 3·281 |
| 5 | 4, 6, 4 | Bland, No. 2 | 3·402 |
| 6 | 6, 5, 3 | „ No. 1 | 3·412 |

"In order to compare the results under the 'string' calculation with those made on the 'squaring' principle, we append a table constructed on the latter plan.

It will be seen that the 'squared' diagrams produce some little difference from the 'strings,' but the main positions are the same. For instance, the average of rook rifles on 'the square' would make Jeffrics one place higher, while the relative positions of Bland's rifles would be altered among the ·500 bores. On the whole, however, the variation is so slight as to show that one method is as good as the other."

THE FOLLOWING TABLE IS CALCULATED ON THE SQUARE FOR THE PURPOSE OF COMPARISON.

## I.—ROOK RIFLES.

| General Position. | Position at respective Ranges. | Makers. | Dimensions and Area of Diagrams. At 50 Yards. | Dimensions and Area of Diagrams. At 75 Yards. | Average of the two ranges. |
|---|---|---|---|---|---|
| | | | Inches. | Inches. | Sq. Inches. |
| 1 | 1, 1 | Holland ............ | 1·2 × 1·2 = 1·44 | 2·2 × 2·5 = 5·50 | 3·47 |
| 2 | 3, 2 | Tranter ............ | 2·4 × 2·7 = 6·48 | 2·9 × 6·0 = 17·40 | 11·94 |
| 3 | 4, 3 | Adams ............ | 2·5 × 2·7 = 6·75 | 3·7 × 4·8 = 17·76 | 12·25 |
| 4 | 2, 6 | Bland ............... | 2·1 × 2·9 = 6·09 | 4·5 × 6·4 = 28·80 | 17·44 |
| 5 | 6, 4 | Jeffries ............ | 2·6 × 4·0 = 10·40 | 3·8 × 5·6 = 21·28 | 15·84 |
| 6 | 5, 5 | Watson ............ | 2·6 × 3·7 = 9·62 | 3·9 × 6·8 = 26·52 | 18·07 |

## II.—EXPRESS RIFLES.

| General Position. | Position at respective Ranges. | Maker and Bore of Rifles. | Dimensions and Area of Diagrams. At 50 Yards. | Dimensions and Area of Diagrams. At 100 Yards. | Dimensions and Area of Diagrams. At 150 Yards. | Average of the three Ranges. |
|---|---|---|---|---|---|---|
| **·400-Bore.** | | | Inches. | Inches. | Inches. | Sq. Inches. |
| 1 | ...... | Holland ...... | 1·5 × 3·6 = 5·40 | 3·25 × 6·5 = 21·12 | 3·7 × 10·5 = 38·85 | 21·79 |
| **·450-Bore.** | | | | | | |
| 1 | 3, 1, 1 | Holland ...... | 2·1 × 4·3 = 9·03 | 2·9 × 5·4 = 15·66 | 3·9 × 4·9 = 19·11 | 14·60 |
| 2 | 2, 2, 2 | Bland, No. 2 | 2·6 × 3·2 = 8·32 | 4·4 × 8·8 = 38·72 | 10·8 × 13·9 = 150·12 | 65·72 |
| 3 | 1, 3, 3 | Bland, No. 1 | 2·1 × 3·1 = 6·51 | 6·2 × 7·5 = 46·50 | 9·5 × 21·8 = 207·10 | 86·70 |
| **·500-Bore.** | | | | | | |
| 1 | 1, 2, 2 | Holland ...... | 1·8 × 2·8 = 5·04 | 3·0 × 3·4 = 10·20 | 5·6 × 6·1 = 34·16 | 16·47 |
| 2 | 2, 1, 3 | Jeffries ...... | 1·9 × 3·6 = 6·84 | 2·0 × 2·8 = 5·60 | 6·5 × 12·8 = 83·10 | 31·85 |
| 3 | 3, 4, 1 | Adams......... | 3·5 × 3·6 = 12·60 | 6·0 × 9·9 = 59·40 | 4·7 × 6·0 = 28·20 | 33·40 |
| 4 | 4, 3, 5 | Bland, No. 2 | 3·0 × 5·5 = 16·50 | 4·5 × 10·0 = 45·00 | 6·0 × 39·0 = 214·00 | 91·83 |
| 5 | 5, 5, 4 | Bland, No. 1 | 4·4 × 5·5 = 24·20 | 6·0 × 11·9 = 71·40 | 8·4 × 15·4 = 129·40 | 75·00 |
| **·577-Bore.** | | | | | | |
| 1 | 3, 1, 1 | Holland ...... | 2·7 × 3·0 = 8·10 | 4·8 × 6·3 = 30·24 | 4·8 × 7·7 = 36·96 | 25·10 |
| 2 | 2, 2, 2 | Adams, No. 2 | 1·6 × 3·5 = 5·60 | 3·8 × 9·8 = 37·20 | 4·3 × 10·7 = 46·01 | 29·60 |
| 3 | 1, 4, 5 | Adams, No. 1 | 1·8 × 2·6 = 4·68 | 7·5 × 7·6 = 57·00 | 6·8 × 18·0 = 122·40 | 61·36 |
| 4 | 5, 2, 6 | Watson ...... | 3·8 × 4·0 = 15·20 | 4·0 × 9·3 = 37·20 | 10·7 × 13·5 = 140·45 | 64·28 |
| 5 | 4, 6, 3 | Bland, No. 2 | 2·5 × 4·3 = 10·75 | 7·0 × 12·2 = 95·16 | 6·8 × 14·9 = 101·30 | 69·07 |
| 6 | 6, 5, 4 | Bland, No. 1 | 4·0 × 6·1 = 24·40 | 8·0 × 10·9 = 87·20 | 8·4 × 13·1 = 110·04 | 73·88 |

"Having now received Major McClintock's trajectories, we have great pleasure in coming to the conclusion that the reliability of the chronograph is completely confirmed by our experiments with the screens. With regard to these, some curious results are brought to our notice by our valued correspondent T., who has kindly examined them, and whose report we append. We insert the two series of curves as drawn by Major McClintock, which show at a glance how small is the variation between them.

As a result of these experiments, we can now positively decide that an Express rifle must have a greater velocity than 1600 feet, if it is desired to shoot "full and fine" with the same sight up to 150 yards, as is the practice of most sportsmen. To do this with success, the ball must not rise and fall much more than two inches from the line of sight, or, in other words, the trajectory must not be more than 4½ inches, or thereabouts, in 150 yards. A valuable and simple definition of the Express is thus obtained, for mere muzzle velocity is not sufficient. To exemplify this, we have only to examine the trajectory of Mr. Jeffries' ·500 bore, which, from its comparatively light bullet, had a very high muzzle velocity, and shot splendidly up to 100 yards, but fell off frightfully at 150 yards, and at that range would be practically useless.

We may now take Messrs. Holland's diagrams as a standard for comparison, and our experience leads us to believe that they will not easily be beaten, or indeed equalled. To obtain such a standard was the main object of our trial. Up to this time sportsmen had no means of ascertaining whether or no they had the best rifles which could be made; but they can now judge for themselves, with the aid of a competent shooter, if they are not themselves up to the mark. It is quite true that all may not desire a rifle to perform well beyond 100 yards; but if it can be got to do well at that distance, and also at the longer range, surely no sportsman can be insensible to the advantage thus obtained. Jeffries' 100 yards string beat, on the average, that of Messrs. Holland's by 1·16 inch; but the latter at 150 yards averaged 2·9 inch against Jeffries' 4·9 inch. Of course, there is a certain amount of luck in making these diagrams, for Messrs. Adams' ·500-bore made a far better diagram at 150 yards than at 100, which can only be accounted for in this way. It is possible, therefore, that Jeffries' 150 yards shoot *may* be thus explained; but the lightness of his bullet would lead us to expect the result, and we believe it to be the true explanation. Numberless other points of great interest are brought out by the trial; but we prefer leaving them to be dealt with more scientifically by our friend T. than we can pretend to do.

With reference to the machine rest, its performance greatly exceeded in accuracy our anticipations, founded on the limited number of trials which we were able to give it. All that is required is to graduate the spring pressure to the charge used; but this could only be done with certainty by experiment, and as we were prevented from resorting to this test by the fear of an injunction, we were compelled to abandon it. On comparing the diagrams made by it in ascertaining the trajectories of Messrs. Holland's rifle, it will be seen that there was little difference from those of Mr. Froome, in some cases being slightly better and in others worse, but those made by it with Messrs. Bland's 450-bore were very superior to the shooting of their assistant. All that it wants to make it a complete substitute for the shoulder is a little practice, and, when this is carried out by Mr. Jones, we expect to hear of its being very generally adopted by gunmakers in regulating their rifles—especially as there is no doubt about its efficacy in regard to shot guns and single rifles."

## String Measurements of the Large-Bores.

"The following are the details of the trial of the large-bores at Nunhead:

### Class VI.—12-Bore.

**Double Rifles**, not exceeding 14lb. in weight, nor more than 28 inches in length; powder, not less than 6drs.; range, 50 yards.

Average string in inches.

**Holland** (weight, 13lb. 8oz.; length, 26½in; powder, 7drs.; recoil, 141lb.)—·30, ·32, ·39, 2·60, 1·24, ·29, ·59, ·79, 1·77, 1·77, 1·63; total, 9·93 .................... ·993

**Bland** (weight, 11lb. 8oz.; length, 28in.; powder, 6drs.; recoil, 132lb.)—4·08, 5·01, 3·51, 3·96, 2·18, 1·77, 2·61, 1·02, 1·44, 1·04; total, 26·62 inches .................... 2·662

### Class X.—No. 12 Smooth-Bore..

**Double Gun**, not exceeding 8lb. in weight, nor more than 30 inches in length; powder, not less than 4drs.; range 50 yards.

**Holland** (weight, 7lb. 8oz.; length, 28in.; powder, 4drs.; recoil 81lb.)—·32, 6·98, 3·72, 4·48, 3·07, 4·75, 2·88, 3·83, 3·85, 2·77; total, 36·65 inches .................... 3·665

**Messrs. Bland absent.**

### Class VII.—10-Bore.

**Double Rifles**, not exceeding 16lb. in weight, nor more than 26 inches in length; powder, not less than 8drs.; range 50 yards.

**Holland** (weight, 12lb.; length, 26in.; powder, 8drs. 5grs.; recoil, 163lb.)—·30, ·40, ·23, 0, 1·83, 1·55, 1·81, 1·76, 1·14, 1·90; total, 10·92 inches .................... 1·092

**Bland** (weight, 12lb. 8oz.; length, 26½in.; powder, 8drs.; recoil, 162lb.)—·67, 4·15, 2·32, ·33, 1·40, ·65, 2·36, 3·57, ·77, 2·21; total, 18·43 inches .................... 1·843

### Class VIII.—8-Bore.

**Double Rifles**, not exceeding 18lb. in weight, nor more than 26 inches in length; powder, not less than 10drs.; range 50 yards.

**Holland** (weight, 17lb. 8oz.; length, 26in.; powder, 10drs; recoil, 185lb.)—1·84, 2·79, ·29, 0, 1·63, 2·45, 1·45, 1·64, 1·71, ·72; total, 14·52 inches .................... 1·452

**Bland** (weight, 17lb.; length, 26in.; powder, 10drs., in Kynoch's brass cases; recoil, over 200lb., the extent of the spring balance in the machine).—2·05, 3·22, ·55, 2·70, 4·67, 3·01, 3·00, 3·82, 2·59, 3·02; total, 28·63 inches .................... 2·863

### Class IX.—4-Bore.

**Double Rifles**, not exceeding 24lb. in weight, nor more than 24 inches in length; powder, not less than 12drs.; range, 50 yards.

**Holland** (weight, 23lb. 8oz.; length, 24in.; powder, 12drs.; recoil could not be taken, owing to want of strength in the spring balance of the machine, which is the largest made by Salter).—·40, ·40, ·31, ·66, ·40, ·45, 1·55, ·73, 1·11, 1·81; total, 7·82 inches ........................................ ·782

Messrs. Bland absent.

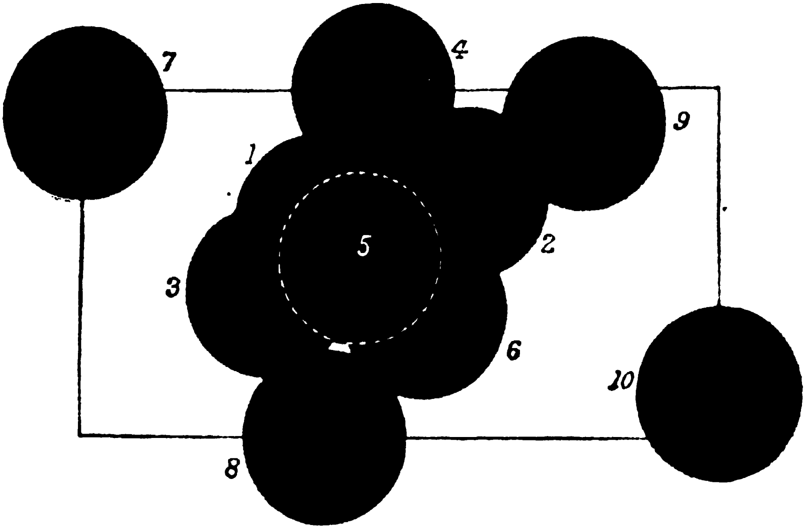

Fig. 123. Holland's 4-Bore at 50 Yards.

## "SQUARED" DIAGRAMS OF LARGE-BORES.

### 12-Bore Rifle.

sq. in. | sq. in.
**Holland**, 3·4 × 3·4 = 11·56 | **Bland**, 5·2 × 8·8 = 45·76

### 12 Smooth-Bore.

**Holland**, 7·6 × 11·2 = 85·12

### 10-Bore Rifle.

**Holland**, 2·7 × 3·8 = 10·26 | **Bland**, 4·6 × 6·8 = 31·28

### 8-Bore Rifle.

**Holland**, 4·2 × 5·0 = 21·00 | **Bland**, 6·8 × 7·0 = 47·60

### 4-Bore Rifle.

**Holland**, 1·8 × 3·5 = 6·30

## NOTES ON THE TRAJECTORIES OF RIFLES AT "THE FIELD" TRIAL AT PUTNEY.

The trial of rifles recently carried out by the Editor of the *Field* having interested me considerably, I have with pleasure accepted his invitation to make a few remarks on the ascertained results with respect to the trajectories of the rifles. But, before proceeding to the trajectories themselves, it may be desirable to give some description of the method by which they were obtained.

A range of 150 yards in length was terminated by a high fence of deal boards, and in grooves upon the smooth surface was slid a piece of thick cardboard, 3ft. square, in the centre of which was printed a black bullseye of 3in. diameter. This formed the target. At intervals of 25 yards each were erected frames to hold the paper screens through which the bullets were to be fired, and which would show the height of the respective projectiles at the distances of 25, 50, 75, 100, and 125 yards, while an additional target was interpolated at 80 yards. This was assumed as about the culminating point of the trajectory, as for several yards the differences are so minute as to be practically non-existent, for recourse must be had to thousandths of an inch to show which is the very highest point. It is therefore not very material whether a yard or two under or over 80 yards be taken, although with light bullets and high velocities the extreme point would be somewhat over; and for heavy bullets of lower speed it would be rather under that distance. This screen was interpolated for the purpose of ascertaining whether there was any noticeable increase of ascent from mid-range to the point at which the bullet would begin to drop towards the 100 yards screen.

The framework of these screens, besides the supports fixed in the ground, consisted of two square 3ft. frames, one of which was crossed at right angles by two tightly-strained wires, so as to form a St. George's cross, and on the other was stretched a sheet of stout paper. The horizontal wires of the six screens were, by means of a dumpy level, ranged exactly even with the middle of the black bullseye on the target, and the centre of the muzzle of the rifle, placed in the machine rest, was made level with the horizontal wires of the screens. When the accuracy of the bearing of the rifle upon the target had been ascertained, the paper-covered frame was put in position, and the second, or wired frame, working upon a hinge, was, after the wires had been painted, raised so as to stand upright against the paper. The pressure of the wires against the paper printed on it a black cross-bar, +, after which the wired frame was let down level with the ground in order that the wires might not be cut by the bullets. Six shots from one rifle having been fired, the perforated sheets of paper and the cardboard target were removed for measurement, new sheets of paper and cardboard being substituted for the next rifle. The necessity for the precautionary removal of the wired frame was shown towards the end of the trials, as the wind became so strong on Thursday that the wires had to be put up as the only way of keeping the paper screens in position; but eventually a bullet cut the wires and stopped further progress—fortunately, however, when the trajectory of only one shot remained to be taken.

In measuring the height of the trajectory at the various ranges, it is obvious that it would not do merely to give the height of the bullet holes in the paper screens, because the bullets do not all strike the targets at the same level, and the bullet-hole represents the height of the trajectory *plus* or *minus* any fluctuations arising from difference in jump of rifle on being fired, or from variation in weight of powder or bullet, or any other disturbing cause. Thus the height of the trajectory itself might in each case be only three or four nches, whereas some bullet-holes would be almost on or near the horizontal black line, and others might be a foot above or below. Consequently, a straight line had to be taken from the muzzle of the rifle to the centre of each bullet-hole on the target, thus cutting off all the adventitious variation, and leaving only the actual trajectory for measurement. Two modes of effecting this were adopted, the whole of the screens being measured by both methods, so that the one served as a check to the other, and any discrepancies between the two caused a repetition of measurement, so as to determine which was the more accurate.

The first measurement was by fastening down on the floor of a long room the cardboard target and six paper screens, forming the series of trajectory records of one rifle. A piece of strong twine, strained tight, was pegged down from one end of the room to the other; under this was laid the paper screens and target, so that the black horizontal lines on the screens ranged immediately under the cord, which also cut the bullseye on the target exactly in the centre. The black vertical lines on the paper screens were placed at a measured distance of 5ft. apart, instead of 25 yards, and consequently the 80ft. screen was only one foot from the 75ft. screen, so as to be in accordance with the same scale. The sheets and cardboard having been tacked down to the floor, a second cord was tightly stretched from one point representing the muzzle of the rifle, to the bullet-hole on the cardboard target 30ft. distant; and from this cord the measurement was made to the position of the bullet on each screen—the level of the bullet being marked by means of a square on the vertical black line of each sheet, so as to make that the actual point of measurement. This was done in order to avoid the error which otherwise would arise from the screens being changed from a vertical plane, as they stood in the range, to a horizontal plane, as they lay on the floor; for two bullet-holes in the same sheet would be equally distant from the rifle as it stood in the range, but they would not be equally distant from the wall (or supposed position of the rifle) when the sheet was nailed down flat on the floor.

Having been furnished with the figures thus obtained, I checked them by another process, which, although it has not the advantage of giving a graphic curve or bird's-eye view of the trajectory, as seen by the method just alluded to, has advantages of another kind, inasmuch as it enables each sheet to be taken up separately, and all the measurements on it to be completed at once; while any sheet can at all times be laid on the table again and re-measured without trouble, should apparent divergences in the figures lead to a doubt as to their accuracy. This method is as follows: A sheet of paper having been ruled into the requisite number of columns for the screens and target, the first screen is laid on the table and the measurement taken from the centre of each bullet-hole to the horizontal black line printed by the wire; the entries for the six shots having been made in one column, the next screen is taken, and the results entered in the second column; and so on until the target is reached, when the measurements are made from a line drawn through the centre of the bullseye. The series of measurements being thus completed, the adventitious variation previously alluded to has to be cut off; and in this case it is done by arithmetic, instead of by a cord. Supposing No. 1 bullet is 6in. above the line on the target (150 yards), it would be a proportionate part of 6in. at all shorter distances, viz., 1in. at 25 yards, 2in. at 50 yards, and so on; if the number is a fractional one, it will have to be divided by 6 in a similar way to get the result for every 25 yards. By this means, the deductions from the whole series can be made in a few minutes, with a similar result to that obtained by the process previously alluded to. Of course, it is desirable to allow several lines of space in writing the entries, so as to give room for making these deductions.

I have entered rather fully into detail on these points in order to show not only the course adopted, but that, where they may seem curious divergences of result, they are not likely to arise from carelessness in measurement. It is not improbable that those which most conflict may have been closely examined and measured half a dozen times over, with a view to account for apparent discrepances. I will not say, however, that at the first screen (25 yards) the measurement is absolutely to be relied on in all cases, for the paper is in some instances so cut about by the bullets being placed one upon another, that it is almost impossible to say where the measurement ought to begin for every bullet. Fortunately, however, a slight error at 25 yards is of little import. For practical purposes, too, I do not think very minute measurements essential. If a sportsman finds the trajectory of his rifle accurate to within the tenth part of an inch, he is not likely to trouble himself about smaller fractions; and the representation of hundredths of an inch are rather confusing to the eye, so that I propose only to resort to them when I have a particular purpose to illustrate; and accordingly, although I have made the measurements as accurately as I could do to hundredths, I shall, as a rule, give the figures only to the nearest tenth.

Taking the rifles as they were tried, the smallest bores first, we begin with—

TRAJECTORY OF MESSRS. HOLLAND'S ·400 BORE.

|  | 25 yds. | 50 yds. | 75 yds. | 80 yds. | 100 yds. | 125 yds. | 150 yds. |
|---|---|---|---|---|---|---|---|
| 1st Shot ... | 1·6 ... | 3·0 ... | 4·2 ... | 4·3 ... | 3·2 ... | 2·2 ... | 0 |
| 2nd „ ... | 2·0 ... | 3·2 ... | 4·5 ... | 4·6 ... | 3·4 ... | 2·4 ... | 0 |
| 3rd „ ... | 1·7 ... | 3·1 ... | 4·3 ... | 4·4 ... | 3·2 ... | 2·2 ... | 0 |
| 4th „ ... | 1·9 ... | 3·2 ... | 4·4 ... | 4·5 ... | 3·3 ... | 2·3 ... | 0 |
| 5th „ ... | 1·6 ... | 3·1 ... | 4·4 ... | 4·5 ... | 3·3 ... | 2·3 ... | 0 |
| 6th „ ... | 1·8 ... | 3·1 ... | 4·3 ... | 4·4 ... | 3·3 ... | 2·3 ... | 0 |
| Average.. | 1·77 | 3·12 | 4·35 | 4·45 | 3·28 | 2·28 |  |

There is not very much to remark on this series of trajectories, except that the first shot seems to have had greater velocity than the rest, its height being less than the others throughout the range; whereas the second shot is higher throughout, which apparently must have resulted from its being below the average in speed. The remaining shots do not vary greatly as compared with one another.

The most remarkable of the whole series of trajectories is that next given; and in this case, in order to show the marvellous uniformity of result obtained, I shall give the figures to hundredths of an inch.

### TRAJECTORY OF MESSRS. HOLLAND'S ·450 BORE.

| | 25 yds. | 50 yds. | 75 yds. | 80 yds. | 100 yds. | 125 yds. | 150 yds. |
|---|---|---|---|---|---|---|---|
| 1st Shot | 2·06 | 3·38 | 4·65 | 4·68 | 3·50 | 2·40 | 0 |
| 2nd " | 2·01 | 3·29 | 4·65 | 4·66 | 3·52 | 2·46 | 0 |
| 3rd " | 2·05 | 3·30 | 4·65 | 4·66 | 3·55 | 2·44 | 0 |
| 4th " | 2·02 | 3·31 | 4·65 | 4·68 | 3·55 | 2·46 | 0 |
| 5th " | 2·03 | 3·32 | 4·65 | 4·67 | 3·57 | 2·47 | 0 |
| 6th " | 2·04 | 3·38 | 4·67 | 4·71 | 3·61 | 2·46 | 0 |
| Average.. | 2·03 | 3·33 | 4·65 | 4·68 | 3·55 | 2·45 | |

If the hundredths were removed, and only the inches and tenths given, there would scarcely be any variation throughout the whole series. This indicates, to my mind, not only great truth in the rifle, but a remarkable degree of accuracy in the weight and the loading of the charges. Had these measurements been taken off successively by a pair of compasses, it might not unnaturally be supposed that, the distances being very much alike, the compasses were never shifted. In fact, however, they were all separate measurements of bullets at different heights on the target, and proportionate allowances had to be made for every screen, as previously described. The following examples, from the 75 yards screen, will show the actual measurement, and the proportionate allowance in each case, as well as the height of trajectory remaining when the deduction has been made:

| Shot 1. | Shot 2. | Shot 3. | Shot 4. | Shot 5. | Shot 6. |
|---|---|---|---|---|---|
| 7·65 | 7·45 | 7.50 | 6·25 | 6·80 | 6·35 |
| 3·00 | 2·80 | 2·85 | 1·60 | 2·15 | 1·68 |
| 4·65 | 4·65 | 4·65 | 4·65 | 4·65 | 4·67 |

These bullets struck the target (150 yards) at the respective heights of 6in., 5·6in., 5·7in., 3·2in., 4·3in., and 3·36in. above the centre of the bullseye, and the allowances for half the distance, or 75 yards, is therefore one-half of these respective heights.

The next rifle, of the same bore as the last, would need no hundredths of an inch to demonstrate the amount of variation; but I give them as affording a better means of comparison in some remarks which I wish to make.

TRAJECTORY OF MESSRS. BLAND'S ·450-BORE.

| | 25 yds. | 50 yds. | 75 yds. | 80 yds. | 100 yds. | 125 yds. | 150 yds. |
|---|---|---|---|---|---|---|---|
| 1st Shot | 1·78 | 2·95 | 4·20 | 4·52 | 2·80 | 2·00 | 0 |
| 2nd " | 2·00 | 3·10 | 4·17 | 4·40 | 2·95 | 2·19 | 0 |
| 3rd " | 2·04 | 3·28 | 4·17 | 4·43 | 3·28 | 2·45 | 0 |
| 4th " | 2·16 | 3·37 | 4·24 | 4·60 | 3·23 | 2·44 | 0 |
| 5th " | 1·73 | 2·92 | 4·15 | 4·32 | 3·08 | 2·16 | 0 |
| Average.. | 1·94 | 3·12 | 4·19 | 4·45 | 3·06 | 2·26 | |

Here the trajectories of five shots only are given, the sixth being off the card at 150 yards, and consequently the height could not be estimated at intermediate distances. It will be observed that the average height at all the screens is less than with Holland's rifle, which indicates a higher velocity in the bullet; but, although there is a fair amount of regularity at some screens, there are considerable divergences from screen to screen, and the variations between 75 and 80 seem to show great vagaries on the part of the bullets. In Holland's trajectories it will be seen that in these five yards (75 to 80) the rise was only about three or four hundredths of an inch, which is so close to the theoretic difference as to indicate that the bullets must have spun with great steadiness during their flight. In Bland's, on the contrary, the difference in the same five yards was nearly ten times as great; and there are strong indications in certain cases that the bullet was not revolving truly on its axis; but probably had a wabbling or corkscrew-like motion, the point rising and dipping from screen to screen. Thus, taking the fourth and fifth shots, there are only ·09 of an inch difference between the height of the two bullets at 75 yards, but the difference at the end of another five yards is ·28; at 100 yards the difference is reduced to ·15, but at 125 yards rises to ·28 again.

The differences were so erratic that I imagined at first that the bullet-holes must have been wrongly numbered, and I accordingly traced each bullet carefully from screen to screen, and the result was to show that certain bullets, after getting beyond the culminating point of the range, and beginning to drop, rose again to the next screen. This, I thought, must be an impossibility, so I measured and re-measured, compared and re-compared, but could find no inaccuracy in the measurement nor any wrong numbering of the bullet-mark. Then I thought the screens might be affected by the wind, the sheet of paper being possibly blown to and fro, and so made to belly like a sail, and thus effect a variation; but this would not meet the case, as Holland's and Bland's rifles were both tried on Tuesday, under similar conditions, there being little or no wind.

Mere differences in height throughout the range, if regular, would indicate difference of velocity, but these fluctuations appear to show irregularity of motion in the bullet. This might arise from the rifle having too slow a twist, and the velocity not being sufficient to give the rapidity of rotation requisite to keep the bullet point foremost; or it might arise from the loading of the cartridge not been carried out with sufficient care, for if a short bullet be not accurately seated in the shell, it is not likely to come out at the muzzle with its point exactly in the centre of the bore, and, instead of rotating with a steady motion, the point will gyrate in a corkscrew fashion, and move up and down as well as deviate to the right and left. That such was the case in some of these instances appears to me to be clear from examination of the screens.

Tracing the respective bullet-marks from screen to screen, noticed that whereas, generally speaking, the divergences of the bullets from the upright black line made by the vertical wire were pretty regular—so that, if you found two bullets at say 1in. and 1½in. from this line at one distance, they would each be about double as far away from the line at double the distance, and so on—yet in certain cases this regularity was not maintained. Thus, two bullets were several inches apart as to height, but about equally distant from the vertical line, except that they zigzagged about, sometimes one of them being nearest to the line and sometimes the other, as will be seen by the following figures :

DISTANCE FROM VERTICAL LINE ON SCREENS.

| | At 50 yds. | 75 yds. | 80 yds. | 100 yds. | 125 yds. | 150 yds. |
|---|---|---|---|---|---|---|
| Bullet 1 | 2·5 | 3·6 | 4·1 | 5·5 | 7·9 | 9·0 |
| „ 3 | 2·4 | 3·8 | 4·0 | 5·6 | 7·2 | 8·0 |

In another case, a group of three bullets formed an equilateral triangle on one of the screens, but on the next screen the apex of the triangle was a good deal to the right, and on the third it was rather to the left; and the divergence of one of the three bullets was so much greater than the others that it did not strike the target-card at all at 150 yards.

If, then, certain bullets rotated irregularly from side to side, they would move in a similar fashion up and down, but such differences are not so obvious, as they are masked by the changes that are produced in the height of the bullet by gravitation ; and when the trajectories are given in figures, as in the foregoing tables, certain differences may be observed, but the cause of them is by no means apparent. Thus, taking shots 2 and 3 in the table of Bland's trajectory, it will be seen that, although both are of exactly the same height at 75 yards, shot 3 is the higher of the two both before and after; and that although shot 1 is highest at 75 and 80 yards, it is below the others at 50, 100, and 125 yards. It is much clearer, however, when the actual heights on the targets are shown, as in the following instance from shot 1:

DISTANCES ABOVE THE HORIZONTAL LINE ON SCREENS.

| | At 50 yds. | 75 yds. | 80 yds. | 100 yds. | 125 yds. | 150 yds. |
|---|---|---|---|---|---|---|
| 1st Shot | 5·75 | 8·40 | 9·00 | 8·40 | 9·00 | 8·40 |
| 2nd „ | 5·22 | 7·36 | 7·80 | 7·20 | 7·50 | 6·38 |
| 3rd „ | 5·20 | 7·05 | 7·50 | 7·12 | 7·25 | 5·75 |
| 4th „ | 4·75 | 6·30 | 6·80 | 5·98 | 5·88 | 4·12 |
| 5th „ | 2·75 | 3·90 | 4·05 | 2·75 | 1·75 | 0·50 |

Here it will be seen that there is always a rise up to 80 yards, and the fluctuations are not apparent, but after the bullet has got beyond 80 yards, it drops, in the case of shot 1, from 9·00 to 8·40, then rises to 9·00 again, and then drops once more to 8·40. In shots 2 and 3 similar divergences occur, but on a smaller scale. The rest of the bullets drop throughout from 80 yards, in the regular way, though not in equal proportion.

All such divergences must necessarily tell most at long ranges, and it is not surprising that, although Messrs. Bland did very well at 50 yards, they fell off at 100, and were nowhere at 150 yards. Whether the fault was in the rifle or the cartridge I cannot say for certain, but my impression is that the cartridges were less carefully loaded than those of their competitor; and, with a lighter bullet and higher velocity, the result was much more obvious at long than at short ranges.*

The next on the list is the ·500-bore, of which it will suffice to give the differences in tenths of an inch:

TRAJECTORY OF MESSRS. HOLLAND'S ·500-BORE.

| | At 25 yds. | 50 yds. | 75 yds. | 80 yds. | 100 yds. | 125 yds. | 150 yds. |
|---|---|---|---|---|---|---|---|
| 1st Shot | 2·0 | 3·4 | 4·7 | 4·8 | 3·6 | 2·5 | 0 |
| 2nd „ | 2·2 | 3·5 | 4·9 | 5·0 | 3·9 | 2·6 | 0 |
| 3rd | 2·1 | 3·3 | 4·4 | 4·5 | 3·4 | 2·1 | 0 |
| 4th | 2·1 | 3·4 | 4·7 | 4·8 | 3·5 | 2.4 | 0 |
| 5th | 2·2 | 3·5 | 4·8 | 4·9 | 3·7 | 2·6 | 0 |
| 6th | 2·1 | 3·5 | 4·8 | 4·9 | 3·7 | 2·6 | 0 |
| Average. . | 2·12 | 3·43 | 4·72 | 4·82 | 3·63 | 2·47 | |

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* All the cartridges used in the trial, except those of Messrs. Holland, were loaded by Eley.—ED.

This rifle, although performing very well on the whole, was not nearly so regular as the ·450-bore of the same maker. The differences in the height of the trajectory—in the second and third shots, for example — indicate a considerable difference in velocity; and the variations in other respects appear to show that there was some of the wabbling motion so apparent in the rifle just alluded to, though in very much less degree. Comparing the screens, I find the following to be the relative distances of two shots from the vertical line, at the ranges stated:

| | At 50yds. | 75yds. | 80yds. | 100yds. | 125yds. | 150yds. |
|---|---|---|---|---|---|---|
| Shot 1 | 1·0 | 1·5 | 1·6 | 1·4 | 1·6 | 2·1 |
| Shot 5 | 0·7 | 1·4 | 1·6 | 1·7 | 2·0 | 2·9 |

It is clear that these two shots, which were nearly one over the other on the same screens, could not be rotating with equal regularity; for one moves inwards towards the line between 80 and 100 yards, and outwards between 100 and 125.

The ·577-bore was the last of the batch, and this series comprises only five shots, as, owing to the strength of the wind on the last day, the wired frames, as already stated, had to be put up to keep the sheets in position, and one was damaged by the last bullet fired. Whether the wind had detrimental effect on the trajectory results I cannot say with certainty, but think it very probable. At any rate, there are differences not found in any of the other records, as may be observed by comparing the following figures:

TRAJECTORY OF MESSRS. HOLLAND'S ·577-BORE.

| | At 25yds. | 50yds. | 75yds. | 80yds. | 100yds. | 125yds. | 150yds. |
|---|---|---|---|---|---|---|---|
| 1st Shot | 1·7 | 3·7 | 5·0 | 4·8 | 3·8 | 2·9 | 0 |
| 2nd „ | 2·0 | 3·5 | 4·7 | 4·8 | 3·7 | 2·5 | 0 |
| 3rd „ | 2·2 | 3·5 | 5·0 | 5·2 | 4·0 | 2·8 | 0 |
| 4th „ | 2·0 | 3·5 | 5·0 | 5·0 | 3·7 | 2·7 | 0 |
| 5th „ | 1·7 | 3·0 | 4·5 | 4·4 | 3·4 | 2·5 | 0 |
| Average | 1·92 | 3·44 | 4·84 | 4·84 | 3·72 | 2·68 | |

Here, in the column for 80 yards, it will be seen that in two instances the height of the trajectory is less than at 75 yards, and in one instance the height is the same in both. With bullets flying truly, if there were no movement in the screen, this would be impossible; and in the case of shot 1, where the height at 80 yards appears to be two-tenths of an inch less than that of 75 yards, I find on the screens no indication of irregularity of flight. In shot 5, however, there is a little irregularity. My impression, however, is that these differences are produced by the effect of the wind on the screens; and as it blew up the range from the target, the paper of the screen at 80 yards might be bellied forward, whereas that at 75 yards, being sheltered by the close proximity of the other screen, was not similarly effected, and a difference of a quarter of an inch or so, might easily be thus produced.

Since working out the above results, I have seen Major McClintock's figures giving the trajectories as ascertained by him from trials with the chronograph, and I find that the heights indicated on the screens are generally about half an inch greater than those calculated from the chronograph times. It seems to me very probable that this increased height may be due to the fact that in the former case the projectiles had to pass through a succession of screens of stout cartridge-paper before reaching the target, and that, as the bullet would not be moving at right angles to the screens, it would during its ascent, receive a slight cant upwards at every contact. We know that the touch of a very small twig will turn the course of a bullet to some extent, and a hairsbreadth at one screen amounts to something more considerable by the time the bullet gets to the next screen, where the process is repeated. This might, I think, easily produce a difference of half an inch in the height of the bullet about mid range. Such appears to me to be highly probable, for I noticed an apparently similar effect produced in the way of lateral deviation. In cases where bullets struck exactly on the upright black line, they kept on the line for several successive screens, and never got far away from it; but if they struck wide, they went away towards the sides more rapidly at times than the mere divergence alone seemed to warrant. This lateral deviation would go on increasing throughout the whole 150 yards, for the course of the bullet would not be changed at mid-distance by the drop. I consider this explanation the more likely, because at the first screen, where there can have been no deflection from such a cause, the height is usually less as taken from the screens than as calculated from the chronograph; and the fact of its thus being less is due, I think, to the allowance made (either by cutting off by a cord, or by arithmetical deduction, as explained at the beginning) being larger, owing to the increased rise, than it would have been had there been no deflection caused by contact with the paper.

In conclusion, I may say that the barometrical variations, and the differences of dry and wet bulb thermometers during the trial were so small, that no appreciable difference could result in so short a range as 150 yards." T.

## TABLES OF TRAJECTORIES, TIMES, &c.

(Calculated by Major W. McClintock, R.A., Assist. Supt., Royal Small Arms Factory, Enfield Lock.)

The heights of trajectory, &c., given in the following tables have been calculated from the mean muzzle velocity, obtained by firing five rounds from each rifle, and from the mean weights of the bullets, found by breaking up and weighing three rounds of each sample of ammunition.

The diagrams of the curves are drawn with the heights on

Here, in the column for 80 yards, it will be seen that in two instances the height of the trajectory is less than at 75 yards, and in one instance the height is the same in both. With bullets flying truly, if there were no movement in the screen, this would be impossible; and in the case of shot 1, where the height at 80 yards appears to be two-tenths of an inch less than that of 75 yards, I find on the screens no indication of irregularity of flight. In shot 5, however, there is a little irregularity. My impression, however, is that these differences are produced by the effect of the wind on the screens; and as it blew up the range from the target, the paper of the screen at 80 yards might be bellied forward, whereas that at 75 yards, being sheltered by the close proximity of the other screen, was not similarly effected, and a difference of a quarter of an inch or so, might easily be thus produced.

Since working out the above results, I have seen Major McClintock's figures giving the trajectories as ascertained by him from trials with the chronograph, and I find that the heights indicated on the screens are generally about half an inch greater than those calculated from the chronograph times. It seems to me very probable that this increased height may be due to the fact that in the former case the projectiles had to pass through a succession of screens of stout cartridge-paper before reaching the target, and that, as the bullet would not be moving at right angles to the screens, it would during its ascent, receive a slight cant upwards at every contact. We know that the touch of a very small twig will turn the course of a bullet to some extent, and a hairsbreadth at one screen amounts to something more considerable by the time the bullet gets to the next screen, where the process is repeated. This might, I think, easily produce a difference of half an inch in the height of the bullet about mid range. Such appears to me to be highly probable, for I noticed an apparently similar effect produced in the way of lateral deviation. In cases where bullets struck exactly on the upright black line, they kept on the line for several successive screens, and never got far away from it; but if they struck wide, they went away towards the sides more rapidly at times than the mere divergence alone seemed to warrant. This lateral deviation would go on increasing throughout the whole 150 yards, for the course of the bullet would not be changed at mid-distance by the drop. I consider this explanation the more likely, because at the first screen, where there can have been no deflection from such a cause, the height is usually less as taken from the screens than as calculated from the chronograph; and the fact of its thus being less is due, I think, to the allowance made (either by cutting off by a cord, or by arithmetical deduction, as explained at the beginning) being larger, owing to the increased rise, than it would have been had there been no deflection caused by contact with the paper.

In conclusion, I may say that the barometrical variations, and the differences of dry and wet bulb thermometers during the trial were so small, that no appreciable difference could result in so short a range as 150 yards." T.

a scale of 2in. to the foot, and the range on the scale of 2in. to 20 yards.

### VELOCITIES.

| Nature of Rifle. | No. of Rounds. | Charge. | | Muzzle Velocity. | Mean Muzzle Velocity. |
|---|---|---|---|---|---|
| | | Powder. | Bullet. | | |
| | | Grains. | Grains. | f.s. | f.s. |
| ·400″ double Express, by Messrs. Holland and Holland, weight 7lb. 14oz., length of barrel 26in. | 1 | 82 | 209 | 1870 | |
| | 2 | ,, | ,, | 1881 | |
| | 3 | ,, | ,, | 1866 | |
| | 4 | ,, | ,, | 1861 | |
| | 5 | ,, | ,, | 1890 | 1873·6 |
| ·450″ double Express, by Messrs. Holland and Holland, weight 8lb. 4oz., length of barrel 26in. | 1 | 110 | 322 | 1785 | |
| | 2 | ,, | ,, | 1739 | |
| | 3 | ,, | ,, | 1788 | |
| | 4 | ,, | ,, | 1804 | |
| | 5 | ,, | ,, | 1764 | 1777 |
| ·500″ double Express, by Messrs. Holland and Holland, weight 9lb. 1oz., length of barrel 28in. | 1 | 138 | 444 | 1786 | |
| | 2 | ,, | ,, | 1773 | |
| | 3 | ,, | ,, | 1784 | |
| | 4 | ,, | ,, | 1784 | |
| | 5 | ,, | ,, | 1793 | 1784 |
| ·500″ double Express, by Mr. Jeffries, weight 8lb. 4½oz., length of barrel 28in. | 1 | 138 | 342 | 1949 | |
| | 2 | ,, | ,, | 1961 | |
| | 3 | ,, | ,, | 1934 | |
| | 4 | ,, | ,, | 1936 | |
| | 5 | ,, | ,, | 1950 | 1946 |
| ·577″ double Express, by Messrs. Holland and Holland, weight 11lb. 10oz., length of barrel, 26in. | 1 | 164 | 591 | 1670 | |
| | 2 | ,, | ,, | 1655 | |
| | 3 | ,, | ,, | 1676 | |
| | 4 | ,, | ,, | 1657 | |
| | 5 | ,, | ,, | 1659 | 1663·4 |

### MESSRS. HOLLAND'S ·400″ DOUBLE EXPRESS RIFLE.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Height of Trajectory. | |
|---|---|---|---|---|---|
| | | | | For 150 Yards. | For 100 Yards. |
| Yards. | f.s. | ft.-lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1874 | 1628 | 0 | 0 | 0 |
| 25 | 1772 | 1455 | 0·04134 | 1·9596 | 1·10376 |
| 50 | 1675 | 1300 | 0·08472 | 3·3060 | 1·5516 |
| 75 | 1581 | 1159 | 0·1311 | 3·9396 | 1·2252 |
| 100 | 1492 | 1032 | 0·1795 | 3·7164 | 0 |
| 125 | 1406 | 916·0 | 0·2315 | 2·4684 | ... |
| 150 | 1326 | 814·9 | 0·2867 | 0 | ... |
| **Highest point of trajectory** ............ | | | | 3·9720 | 1·5552 |

## Messrs. Holland's ·450″ Double Express Rifle.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Height of Trajectory. | |
|---|---|---|---|---|---|
| | | | | For 150 Yards. | For 100 Yards. |
| Yards. | f.s. | ft.-lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1776 | 2254 | 0 | 0 | 0 |
| 25 | 1696 | 2055 | 0·04301 | 2·0772 | 1·18656 |
| 50 | 1618 | 1869 | 0·08847 | 3·4932 | 1·6644 |
| 75 | 1543 | 1700 | 0·1358 | 4·1244 | 1·3116 |
| 100 | 1470 | 1544 | 0·1858 | 3·8436 | 0 |
| 125 | 1400 | 1400 | 0·2383 | 2·5128 | ... |
| 150 | 1335 | 1274 | 0·2929 | 0 | ... |
| Highest point of trajectory ............ | | | | 4·1436 | 1·6680 |

## Messrs. Holland's ·500″ Double Express Rifle.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Height of Trajectory. | |
|---|---|---|---|---|---|
| | | | | For 150 Yards. | For 100 Yards. |
| Yards. | f.s. | ft.-lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1784 | 3134 | 0 | 0 | 0 |
| 25 | 1712 | 2887 | 0·04270 | 2·0148 | 1·15872 |
| 50 | 1641 | 2653 | 0·08798 | 3·3816 | 1·6188 |
| 75 | 1573 | 2436 | 0·1346 | 3·9600 | 1·2636 |
| 100 | 1507 | 2237 | 0·1832 | 3·6696 | 0 |
| 125 | 1443 | 2051 | 0·2340 | 2·3916 | ... |
| 150 | 1382 | 1939 | 0·2869 | 0 | ... |
| Highest point of trajectory ............ | | | | 3·9768 | 1·6212 |

## Mr. Jeffries' ·500″ Double Express Rifle.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Height of Trajectory. | |
|---|---|---|---|---|---|
| | | | | For 150 Yards. | For 100 Yards. |
| Yards. | f.s. | ft.-lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1946 | 2872 | 0 | 0 | 0 |
| 25 | 1846 | 2584 | 0·03967 | 1·7904 | 1·01388 |
| 50 | 1750 | 2323 | 0·08139 | 3·0192 | 1·4244 |
| 75 | 1658 | 2085 | 0·1254 | 3·5844 | 1·12872 |
| 100 | 1569 | 1867 | 0·1720 | 3·3696 | 0 |
| 125 | 1484 | 1671 | 0·2210 | 2·2368 | ... |
| 150 | 1402 | 1490 | 0·2734 | 0 | ... |
| Highest point of trajectory ............ | | | | 3·6108 | 1·4292 |

MESSRS. HOLLAND'S ·577″ DOUBLE EXPRESS RIFLE.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Height of Trajectory. | |
|---|---|---|---|---|---|
| | | | | For 150 Yards. | For 100 Yards. |
| Yards. | f.s. | ft.-lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1663 | 3625 | 0 | 0 | 0 |
| 25 | 1594 | 3332 | 0·04623 | 2·3448 | 1·3476 |
| 50 | 1527 | 3056 | 0·09448 | 3·9108 | 1·8732 |
| 75 | 1463 | 2806 | 0·1440 | 4·5840 | 1·4772 |
| 100 | 1400 | 2569 | 0·1971 | 4·2504 | 0 |
| 125 | 1341 | 2357 | 0·2519 | 2·7684 | ... |
| 150 | 1286 | 2169 | 0·3088 | 0 | ... |
| Highest point of trajectory ........... | | | | 4·6068 | 1·8756 |

## RIFLES FOR LARGE GAME.

### THE TRAJECTORIES, TIMES OF FLIGHT, REMAINING VELOCITIES, AND STRIKING ENERGIES OF BULLETS FIRED FROM LARGE BORE AND EXPRESS RIFLES.

(Calculated by Major W. McCLINTOCK, R.A., Assist. Supt., Royal Small Arms Factory, Enfield Lock.)

To any one who is about to purchase a battery of rifles for large game shooting, it will no doubt be interesting to know the trajectories, and smashing power (striking energy), which the bullets fired from such rifles have, when suitable charges are used. It is with the object of supplying such information that the following tables have been drawn up, which give the remaining velocity, the striking energy, time of flight, and heights of trajectory for every 20 yards, up to a range of 150 yards. The heights of trajectory for 100 yards range have also been given.

In addition to the heights of the trajectories given in the tables, diagrams of the curves have also been drawn, having the heights exaggerated for the sake of clearness—the height being given on the scale of 2in. to the foot, and the range on the scale of 2in. to 20 yards.

From the two heavy rifles (4 and 8 bore) both conical and spherical bullets were fired, so the reader can form his own opinion as to the relative merits of these projectiles.

The observed velocities were found by means of the Boulengé chronograph, and the muzzle and remaining velocities, times of flights, and heights of trajectory, were calculated with the aid of Professor Bashforth's tables.

Curtis and Harvey's "treble strong" powder was used for all the charges (Martini-Henry cartridges excepted), No. 7 powder for the 4-bore rifle, and No. 6 for the other calibres.

Although the Martini-Henry rifle was not designed for sporting purposes, similar information respecting its powers is given. In order to estimate the superiority of the Martini-Henry rifle, the comparison should have been made with a greater range than 150 yards.

The accuracy of rifle bullet trajectories calculated by means of Professor Bashforth's tables has been tested by firing a large number of rounds through paper screens placed at different points along the range. The rifle used in the experiment was the Martini-Henry, and the screens were erected at intervals along a 500 yards and a 1000 yards range.

### 0·45IN., SINGLE-BARREL, MARTINI-HENRY RIFLE (CONICAL BULLET).

Powder, 85grs. Bullet, 480grs.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Heights of Trajectory. 150 Yards Range. | Heights of Trajectory. 100 Yards Range. |
|---|---|---|---|---|---|
| Yards. | f. s. | ft. lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1315 | 1841 | 0 | 0 | 0 |
| 20 | 1283 | 1752 | 0·04555 | 2·9076 | 1·7280 |
| 40 | 1252 | 1669 | 0·09287 | 5·0772 | 2·6712 |
| 60 | 1222 | 1590 | 0·1419 | 6·4128 | 2·7384 |
| 80 | 1194 | 1518 | 0·1911 | 6·8208 | 1·8720 |
| 100 | 1167 | 1450 | 0·2418 | 6·2628 | 0 |
| 120 | 1141 | 1387 | 0·2944 | 4·6356 | |
| 140 | 1116 | 1325 | 0·3484 | 1·8516 | |
| 150 | 1104 | 1297 | 0·3759 | 0 | |

| Arms. | Weight. | | Length of Barrel. | Charge. | | Proportion of weight of powder to weight of bullet. | Muzzle Velocity. |
|---|---|---|---|---|---|---|---|
| | | | | Powder. | Bullet. | | |
| | lb. | oz. | in. | grs. | grs. | | f. s. |
| 0·45 single barrel Martini-Henry Rifle............ | 9 | 0 | $33\frac{3}{16}$ | 85 R. E. F. 2 | 480 conical | 1 : 5·64 | 1315 |
| 4-bore single barrel Elephant Rifle.............. | 20 | 0 | $25\frac{1}{8}$ | 328·08 or 12drs.<br>C. and H. No. 7* | 1882 conical<br>1250 spherical | 1 : 5·73<br>1 : 3·81 | 1330<br>1460 |
| 8-bore double barrel Elephant Rifle ........... | 16 | 4 | 26 | 233·4 or 10drs.<br>C. and H. No. 6 | 1257 conical<br>862 spherical | 1 : 4·59<br>1 : 3·15 | 1500<br>1654 |
| 0·45in. double barrel Express Rifle.............. | 10 | 0 | 26 | 150·37 or 5½drs.<br>C. and H. No. 6 | 274 conical | 1 : 1·822 | 2000 |
| 10-bore double barrel smooth bore Jungle Gun | 10 | 2 | $25\frac{3}{4}$ | 136·7 or 5drs.<br>C. and H. No. 6 | 698 spherical | 1 : 5·106 | 1316 |

* The gunmakers (Messrs. J. and W. Tolley) from whom the arms (except the Martini-Henry rifle) and cartridges were obtained for the purpose of ascertaining the velocities, state that the powder with which the cartridges were loaded was of Messrs. Curtis and Harvey's manufacture.

### 4-Bore Conical Bullet of 1882grs.; Powder, 12drs.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Heights of Trajectory. | |
|---|---|---|---|---|---|
| | | | | 150 Yards Range. | 100 Yards Range. |
| Yards. | f. s. | ft. lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1330 | 7387 | 0 | 0 | 0 |
| 20 | 1293 | 6981 | 0·04516 | 2·8860 | 1·7232 |
| 40 | 1257 | 6597 | 0·09268 | 5·0736 | 2·6880 |
| 60 | 1223 | 6244 | 0·1413 | 6·4056 | 2·7708 |
| 80 | 1191 | 5923 | 0·1908 | 6·8280 | 1·9164 |
| 100 | 1160 | 5619 | 0·2428 | 6·2472 | 0 |
| 120 | 1131 | 5342 | 0·2954 | 4·5996 | |
| 140 | 1104 | 5088 | 0·3485 | 1·8516 | |
| 150 | 1091 | 4969 | 0·3760 | 0 | |

### 4-Bore Spherical Bullet of 1250grs.; Powder, 12drs.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Heights of Trajectory. | |
|---|---|---|---|---|---|
| | | | | 150 Yards Range. | 100 Yards Range. |
| Yards. | f. s. | ft. lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1460 | 5912 | 0 | 0 | 0 |
| 20 | 1375 | 5242 | 0·04234 | 2·7840 | 1·6056 |
| 40 | 1296 | 4659 | 0·08744 | 4·9908 | 2·5524 |
| 60 | 1224 | 4155 | 0·1349 | 6·4632 | 2·7000 |
| 80 | 1158 | 3718 | 0·1854 | 7·0692 | 1·9008 |
| 100 | 1099 | 3351 | 0·2385 | 6·6516 | 0 |
| 120 | 1047 | 3039 | 0·2946 | 5·0208 | |
| 140 | 1001 | 2777 | 0·3538 | 1·9812 | |
| 150 | 981 | 2869 | 0·3828 | 0 | |

### 8-Bore Conical Bullet of 1257grs.; Powder, 10drs.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Heights of Trajectory. | |
|---|---|---|---|---|---|
| | | | | 150 Yards Range. | 100 Yards Range. |
| Yards. | f. s. | ft. lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1500 | 6273 | 0 | 0 | 0 |
| 20 | 1451 | 5870 | 0·04032 | 2·3400 | 1·3800 |
| 40 | 1403 | 5487 | 0·0825 | 4·1172 | 2·1516 |
| 60 | 1357 | 5135 | 0·1261 | 5·2308 | 2·2272 |
| 80 | 1313 | 4807 | 0·1714 | 5·6124 | 1·5276 |
| 100 | 1272 | 4511 | 0·2175 | 5·1792 | 0 |
| 120 | 1233 | 4237 | 0·2652 | 3·8724 | |
| 140 | 1196 | 3989 | 0·3150 | 1·5696 | |
| 150 | 1178 | 3870 | 0·3408 | 0 | |

### 8-Bore Spherical Bullet of 862grs.; Powder, 10drs.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Heights of Trajectory. | |
|---|---|---|---|---|---|
| | | | | 150 Yards Range. | 100 Yards Range. |
| Yards. | f. s. | ft. lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 1654 | 5232 | 0 | 0 | 0 |
| 20 | 1546 | 4569 | 0·03736 | 2·2548 | 1·2828 |
| 40 | 1446 | 3998 | 0·07741 | 4·0764 | 2·0592 |
| 60 | 1354 | 3505 | 0·1203 | 5·3400 | 2·2044 |
| 80 | 1270 | 3084 | 0·1662 | 5·9016 | 1·5696 |
| 100 | 1193 | 2720 | 0·2151 | 5·6052 | 0 |
| 120 | 1125 | 2419 | 0·2665 | 4·2996 | |
| 140 | 1065 | 2169 | 0·3213 | 1·7820 | |
| 150 | 1038 | 2069 | 0·3500 | 0 | |

### 10-Bore, Double-Barrel, Smooth-Bore, Jungle Gun (Spherical Bullet).

Powder, 5drs. Bullet, 698grs.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Heights of Trajectory. |
|---|---|---|---|---|
| | | | | 100 Yards Range. |
| Yards. | f. s. | ft. lb. | Seconds. | Inches. |
| At Muzzle. | 1316 | 2681 | 0 | 0 |
| 20 | 1226 | 2328 | 0·04731 | 2·0316 |
| 40 | 1146 | 2033 | 0·0980 | 3·2484 |
| 60 | 1077 | 1797 | 0·1515 | 3·4548 |
| 80 | 1017 | 1601 | 0·2096 | 2·4300 |
| 100 | 966 | 1445 | 0·2696 | 0 |

### 0·45in., Double-Barrel, Express Rifle (Conical Bullet).

Powder, 5½drs. Bullet, 274grs.

| Range. | Velocity. | Striking Energy. | Time of Flight. | Heights of Trajectory. | |
|---|---|---|---|---|---|
| | | | | 150 Yards Range. | 100 Yards Range. |
| Yards. | f. s. | ft. lb. | Seconds. | Inches. | Inches. |
| At Muzzle. | 2000 | 2431 | 0 | 0 | 0 |
| 20 | 1917 | 2234 | 0·03063 | 1·3932 | 0·8100 |
| 40 | 1837 | 2051 | 0·06256 | 2·4588 | 1·2672 |
| 60 | 1759 | 1880 | 0·09612 | 3·1560 | 1·3260 |
| 80 | 1684 | 1724 | 0·1309 | 3·4176 | 0·92568 |
| 100 | 1611 | 1578 | 0·1675 | 3·1908 | 0 |
| 120 | 1541 | 1443 | 0·2053 | 2·4108 | |
| 140 | 1472 | 1317 | 0·2456 | 0·97248 | |
| 150 | 1439 | 1258 | 0·2661 | 0 | |

# BOOK VI.
# MODERN RIFLED PISTOLS.

## CHAPTER I.
## REVOLVERS.

By whom and where was the first revolver pistol made? This is a question easy to ask, but impossible to answer. If a satisfactory reply could be found, the interest excited would possess more antiquarian than practical value. Following out the purpose of this book, I shall content myself with such reference to the earlier types of revolver as may be necessary to an intelligent understanding of the process of mechanical evolution by which the modern revolvers have come into existence. As the pistol was developed from the previously existing gun, so the revolver seems to have sprung from an early invention of a revolving cylinder applied to a musket. Samples of muskets, having a fixed barrel, with a revolving cylinder containing several chambers, date as far back as the early part of the sixteenth century. To reduce these shoulder weapons to the size of a pistol would be so easy, that we may take it for granted that the first attempts at producing revolver pistols would follow closely on the introduction of revolver muskets. The first idea—common alike to the revolver musket and the revolver pistol—was simply to supply a weapon which should carry several charges. The inventors of these early weapons, therefore, contented themselves with the production of arms in which the several chambers were brought in succession to the barrel by rotating the cylinder by hand; the cocking of the lock being performed by a separate operation. As, however, the object of the revolver principle was greater quickness and facility of fire than was obtainable with the single loading weapons, a desire naturally arose to find means to do away with the need of rotating and adjusting the cylinder by hand. The result sought for was achieved in two distinct ways. One was to cause the pull of the trigger to rotate the cylinder, the other to cause the cocking of the hammer to effect this purpose. In this way the revolver principle started on two separate paths of development; and the differences arising from this divergence are very noticeable in the English and American revolvers of the present day. The English makers chiefly produced revolvers of single action worked by the trigger; while the Americans made single-action revolvers, in which the rotation of the cylinder was performed by cocking the hammer, and the trigger merely discharged the weapon. With the English makers, therefore, the careful study of the position of the centres, and the smoothness of the pull, were matters of the first importance, if accurate shooting was to be obtained. With the Americans, on the other hand, the force required for cocking was of no moment as affecting the shooting; and, in American revolvers, little care was bestowed on the pitch of the centres, and the arrangement of the mainspring and its adjuncts. Until a comparatively recent period few knew of, much less troubled themselves about, this difference between the two leading types of revolvers. One man fancied and bought a trigger-action pistol, another preferred the cocking action; and the merits and defects of each were accepted as part and parcel of the weapon chosen. But, when the call for double-action revolvers arose, a new light was shed on the subject. The English makers already had developed a well-designed and smooth trigger action, and had only to add a cocking action to produce a good double-action revolver. The Americans added a trigger action, but, in so doing, they signally failed to produce a good double action, and made evident the faulty design of their revolving mechanism. It will, therefore, be seen that the English and American revolvers approached the double action stage of development from different directions; and the keeping of this fact in mind will greatly facilitate the understanding of the merits and faults of the various modern types of revolvers.

The first application of the revolver principle of construction, where several chambers were rotated behind one barrel, dates back to the days of matchlocks. Of this type of arm an example exists in the Tower collection, and its period of construction may be set down as previous to 1550.

The flint lock was applied to revolving firearms very soon after its application to single barrelled weapons. Great ingenuity was displayed in the construction of both matchlock and flintlock revolvers, and one cannot fail to be struck by the talent and perseverance of the early inventors, who worked uphill under difficulties that are now almost beyond our comprehension. Triumphs of mechanical ingenuity are to be found in still existent arms of early date, where the makers had more or less successfully tried to cope with the hard problem of producing an efficient type of revolver carrying the necessary flash pans and priming for match or flint locks. The introduction of the percussion system of ignition greatly smoothed the path of the revolver maker, but the exploded cap was apt to clog the revolution, and it was not until the invention of the gas-tight cartridge, carrying its own ignition, that a perfectly reliable weapon for defence became a mechanical possibility. Little profit would ensue from following out the use of rim and pin-fire cartridges in revolvers. All those of the present day are made for use with the central fire cartridge, and practical, as apart from antiquarian, interest does not require an examination extending beyond those weapons which have been the immediate predecessors of the central fire revolvers now used. To Messrs. Smith and Wesson, of Springfield, Massachusetts, is assigned the merit of first producing metallic cartridges for use in revolver pistols, though Flobert, of Paris, used a powerful copper breech cap, containing a bullet, for his pistols in 1853. The development of the modern revolver may therefore be considered as embraced within the last thirty years.

It is true that Colonel Colt patented his revolver in 1835, but this was practically a muzzle loader fitted with nipples for ordinary caps, and it was of the cocking action type. For years previously English makers had turned out considerable numbers of six-barrelled revolvers of the type known as the "pepper-box." The old pepper-box pistol is worthy of note, because the trigger action rotated the barrels. At this time, therefore, we see the revolver separate into the two different types of construction of which I have already spoken, namely, those weapons in which the rotation of the cylinder was effected by cocking the hammer, and those in which the pull of the trigger rotated the cylinder and discharged the pistol. This period therefore affords the best starting point for a purely practical consideration of the modern revolver.

Amongst English makers the above-mentioned actions were not long left separate, for about 1855 the double-action revolver was produced, Adams's being probably the first, or, if not the first made, certainly the first well known. Quickly following came Tranter's double-trigger revolver, an arm of great merit and ingenuity. And in any work dealing with revolvers or other pistols the name of Tranter should hold a place of honour, as belonging to a man who, by many improvements, has done as much as anyone to advance the art of pistol making. Since his time the improvements, numerous and important as they are, have been chiefly in matters of detail, as we shall hereafter see.

The modern revolvers which are being made by the leading manufacturers may be classified as follows:

### I.—SOLID FRAME, NON-EXTRACTING.

Single action, cocking by thumb. Examples: Colt's ·44 Frontier, Colt's ·44 cal.

Double action, cocking by trigger or thumb. Examples: Adams's Double Action, Tranter's Double Action, Colt's Double Action, Webley's No. 5, Webley's Royal Irish Constabulary, Webley's Metropolitan Police, Webley's British Bulldog.

### II.—JOINTED FRAMES, EXTRACTING.

Single action, cocking by thumb. Example: Smith and Wesson.

Double action, cocking by trigger or thumb. Examples: Smith and Wesson, Tranter's, Webley's W.G., Webley's British Army Model, and the Liege Revolver, sold by Messrs. Bland and others in England.

Beyond doubt public opinion is running very strongly in favour of double-action extracting revolvers, and the single-action revolver will soon be a thing of the past; and for home use probably even the double-action non-extracting type cannot long continue to hold its own against the double-action extracting weapon.

The revolver is pre-eminently a weapon for quick work at close quarters, and all other considerations must eventually yield to rapidity of fire and quick reloading. Next to these two paramount conditions come accuracy of fire, length of range, quick sighting, penetrating power, stopping power, safety to the user, endurance of the pistol, and facility for cleaning. These requirements can only be met by a double-action revolver with extracting and ejecting mechanism, and provided with some trustworthy safeguard against the discharge of the weapon until securely bolted. As the greater includes the less, a consideration of the points of such a revolver will cover all those other types of arm which perform only a part of the above-mentioned functions.

(*a*) Rapidity of fire. So far as the discharge of that number of shots contained in one loading of the chamber, non-extracting double-action revolvers may be fired as rapidly as the extracting and ejecting weapons ; but, as soon as the reloading question comes in as part of the attainment of quick fire, the latter weapon leaves the former hopelessly in the rear, and in situations of continued peril the user's life may depend on the facility for reloading.

(*b*) Accuracy of fire. No single trigger action revolver can give the same accuracy that can be obtained with a pistol that can be cocked by the thumb, although rapidity may be secured. Accuracy can be obtained with a single cocking action, but rapidity is entirely wanting. We are therefore compelled to have the double-action extracting revolver if we are to secure a combination of accuracy and a capability of extreme rapidity when required.

(*c*) Length of range. This quality depends upon the weight and form of the bullet, the charge of powder, the proper design of the chambers and barrel, and the accuracy and general solidity achieved in the fitting of the pistol. Each type of revolver must be judged by its actual performance.

(*d*) Quick sighting. This is a most important point in a revolver, but too generally neglected. It is well known to those experienced in revolver shooting that the deep and narrow V usually cut for a backsight, is useless for any but the most leisurely aiming. What is wanted is an arrangement of backsight such as shall enable the shooter to see his foresight plainly for elevation before centring for lateral accuracy.

(*e*) Penetrating power depends on the velocity, weight, shape, and hardness of the bullet, and must not be confused with stopping power. Mere penetrating power should not be sought in a revolver to the neglect of other qualities.

(*f*) Stopping power is one of the most important qualities that a revolver can possess. Most revolvers are wanting in this requirement, as they are too light and of small calibre. A heavy bullet of large calibre, propelled at a moderate velocity, will give the maximum stopping power of which a revolver is capable, because the recoil arising from attempting too much in a revolver soon puts the weapon beyond the use of ordinary men.

(*g*) Safety to the user. This very important quality depends on the design, workmanship, and materials of the revolver. The most fertile source of danger has arisen from the liability of extracting revolvers to be fired without being securely closed. So far I have only met with one safety contrivance to make this impossible.

(*h*) Endurance of the pistol depends, to a great extent, on the design, but still more on the materials and the perfection of the hardening and fitting; and each manufacturer's revolvers must be judged by results.

(*i*) Facility for cleaning is very important if revolvers are to be kept in good shooting condition. In all the modern types this condition seems to have been fairly well studied.

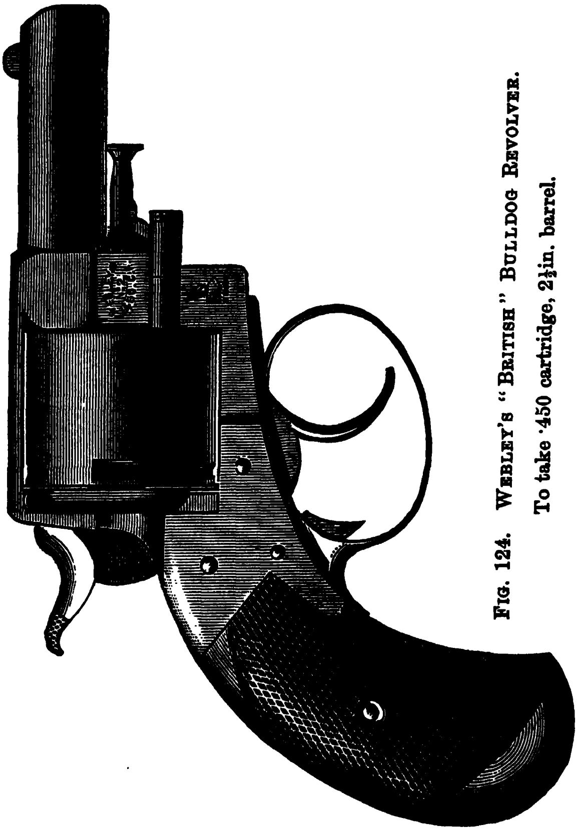
## I. Solid Frame Non-extracting Revolvers.

The following may be taken as examples sufficient to cover all of note: Adams's; Webley's British Bulldog; Webley's

Metropolitan Police, the Royal Irish Constabulary, and the Webley No. 5; Colt's ·45 and Frontier ·44.

All these pistols possess the common features of a solid frame, and a rod for extracting the fired cases.

Webley's "British" Bulldog (built on the lines of the American single action Bulldog) is double action, designed for the ·450 service cartridge, and is the most powerful pocket revolver in the market. A good shot can make a 2in. diagram at 10 yards with this pistol, though it has but a 2½in. barrel.



SCALE ⅔ SIZE.

FIG. 124. WEBLEY'S "BRITISH" BULLDOG REVOLVER.

To take ·450 cartridge, 2½in. barrel.

Colt's ·45 pistol is a very formidable weapon, having a barrel 7½in. long, and weighing 2lb. 8oz.

This pistol shoots a bullet of 250grs., with a charge of 38grs. of powder; and of its power there is no question. But its recoil is very great, and only bearable to men of very strong physique; moreover, its pull-off, as usually sold, is not conducive to good shooting. Its length of barrel and general build make it almost like a small carbine. It is both single and double acting.

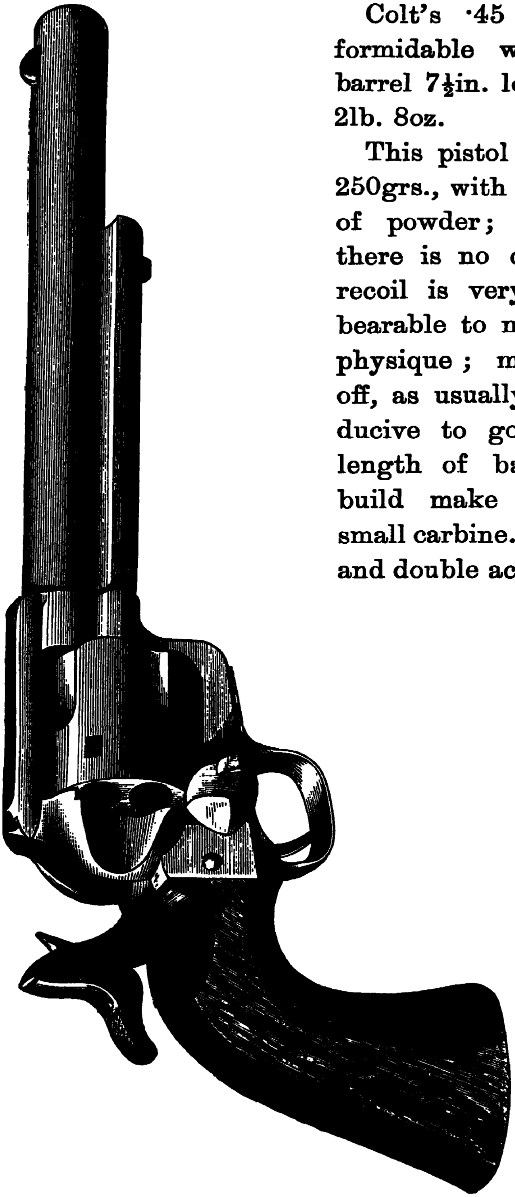


Fig. 127. Colt's Single Action Revolver, 7½in. Barrel.

Both the single and double action Colt revolvers are made with the two lengths of barrel, and to take either American or English cartridges; but the same revolver will not use both.

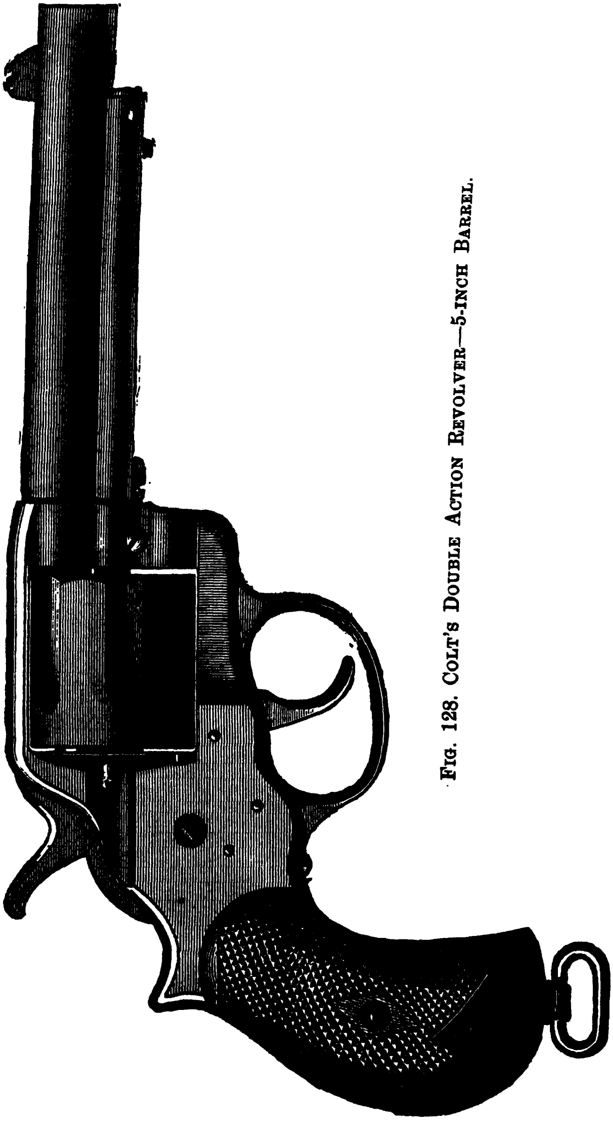


Fig. 128. Colt's Double Action Revolver—5-inch Barrel.

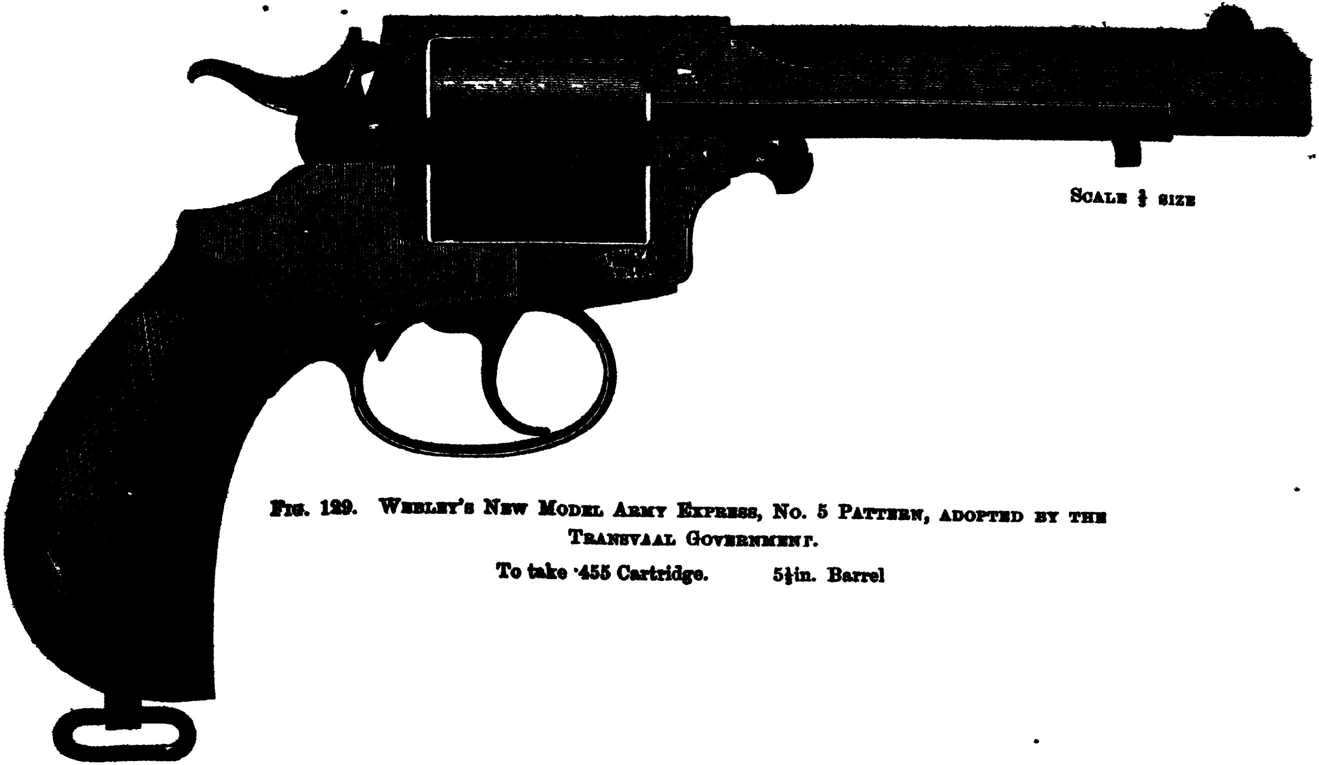


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FIG. 129. WEBLEY'S NEW MODEL ARMY EXPRESS, NO. 5 PATTERN, ADOPTED BY THE TRANSVAAL GOVERNMENT.

To take ·455 Cartridge. 5½in. Barrel

The Colt ·44 Frontier differs only from the above in its cartridge, which contains 40grs. of powder, propelling a bullet of 200grs. The recoil of this pistol is very heavy. Webley's Metropolitan Police Revolver—adopted by the authorities in Nov. 1883—is a weapon of ·450 calibre, with a 2½in. barrel, designed for close quarters and great stopping power. This pistol is double-acting. Webley's Royal Irish Constabulary is also a double-acting weapon, similar to the above, but with a 4½in. barrel, and, therefore, suited for longer ranges than the Metropolitan Police model. This is the pistol used by the Cape Mounted Police, and adopted by the Queensland and Victorian Governments. The latest models of this pistol are ·455 cal. Webley's Army Express, No. 5, which is the revolver adopted by the Government of the South African Republic, is a very powerful weapon, having a 5½in. barrel, and carrying either a ·455 cartridge, or the U.S. ·45 service cartridge. It is of the double-action type. In point of rapidity these double-action pistols have a great advantage over the American single action, and they have also the advantage of a better pull-off when cocked, for the reason already pointed out (see Fig. 129).

The Adams' revolver, though first produced as a muzzle-loader, has been for many years a breech-loading pistol. It is a powerful weapon of the solid frame, non-extracting class, and gives fairly good shooting with the trigger action; but it has not kept pace with the march of improvement in details of design.

## II. JOINTED FRAME EXTRACTING REVOLVERS.

With single action, the best known type is the Smith and Wesson. This is a powerful pistol, but slow in action, and its pull-off is not suited for accurate shooting. In reloading it comes up to the standard of other extracting revolvers.

Smith and Wesson produce an excellent type of double-action extracting revolver, quick in action, and very handy for reloading, but not so good on the trigger action as the English revolvers.

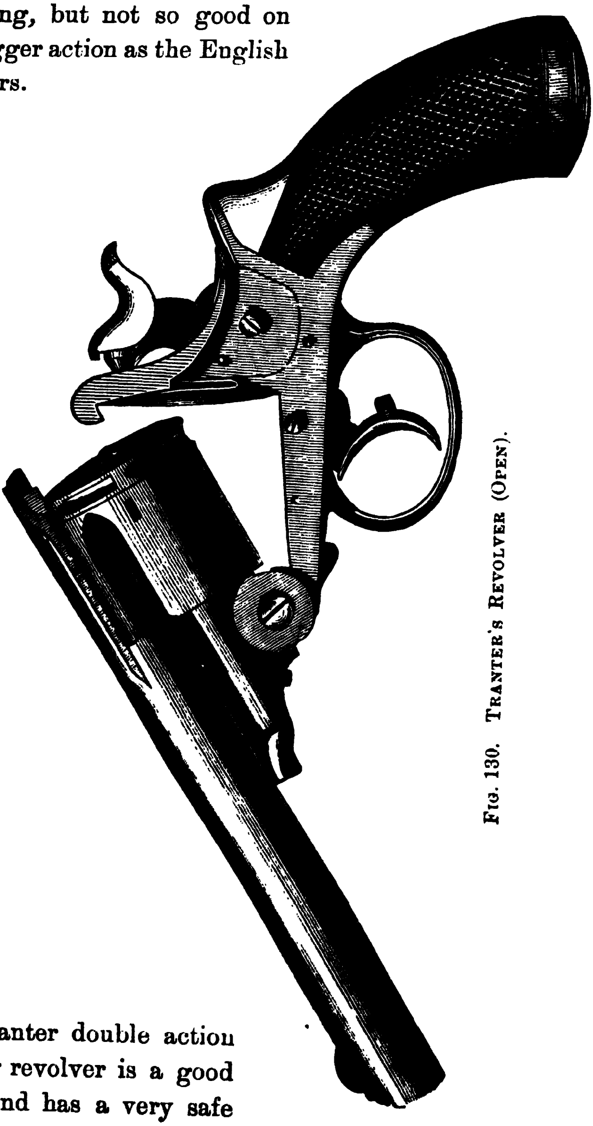

Fig. 130. Tranter's Revolver (Open).

The Tranter double action extracting revolver is a good weapon, and has a very safe and efficient arrangement for locking the strap to the body (see Fig. 130).

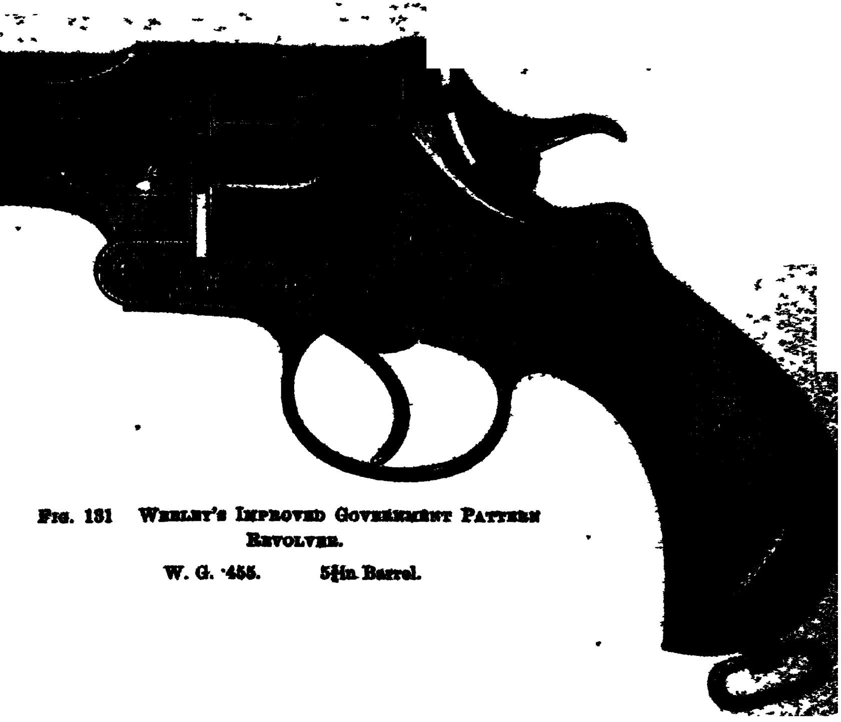

FIG. 131 WEBLEY'S IMPROVED GOVERNMENT PATTERN REVOLVER.

W. G. ·455. 5¾in Barrel.

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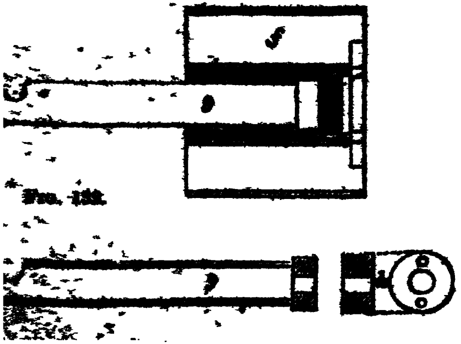

FIG. 132.

Of the Webley double-action extracting revolvers I give illustrations, showing their No. 4 or 4½ ·455 cal., and also a detailed description of their W.G. revolver, which embraces the latest features of revolver development. A recent improvement in these revolvers is the addition of the automatic safety block, which prevents the possibility of discharging the pistol unless securely bolted.

### WEBLEY'S IMPROVED GOVERNMENT PATTERN REVOLVER.

IN this weapon the conditions which have been pointed out, as appertaining to a perfect revolver, are more nearly approached than in any other pistol yet introduced. The following description of this revolver will render its construction and capabilities as understandable as may be without practical experience of the pistol on the part of the reader. Before discussing the very ingenious peculiarities of the lock mechanism, it may be well to describe the general features of the arm. Fig. 131 shows a revolver ·455 calibre, of the double-action extracting type. Taking the body movements, as apart from the lock mechanism, the cylinder rotates upon a hollow spindle (*g*), Fig. 132. It is held in position on this spindle by the anti-friction nut (*h*), which fixes the horizontal position of the cylinder. This anti-friction nut is entirely removed from the influence of the fouling of the flash; and thus this pistol will fire almost any number of rounds without sticking. In fact, as many as 2000 rounds have been fired from one of these pistols; and, after this test, the cylinder was found to be quite free, although the shooting was as rapid as possible, and no cleaning was allowed. This nut also affords a very handy means of attaching and detaching the cylinder from the hollow spindle. The extension rib of the barrel is bolted to the body in a simple and ingenious manner, and one possessed of great strength, inasmuch as nothing less than the double shearing of a steel pin could permit the revolver to fly open, when once bolted. In the body at the right side is a short spring bolt to engage in the hole in the strap. In the strap is a steel bolt or pin, just filling its entire width. In the body, at the left side, is a third bolt or pin. When the pistol is shut, these three bolts form *one* bolt in three parts, and the action is as follows: Commencing from the right, number one, urged by the spring, enters partly into the strap, bolting that side of the strap. The central division of the bolt—that in the strap—is thus forced towards the left, and one end of it enters the left side of the body; and thus the strap is bolted to the body right and left. The third division of the bolt—that in the left side of the body—is thus caused to protrude from the outside to the left, as much as the spring has moved the three components. Pressure on this third component affords the means of unbolting the pistol. Thus it will be seen that this pistol is double bolted by a mechanical arrangement which acts as one bolt. The snap action is secured by suitable inclines on the right hand and middle components. By means of the side lever, the compound bolt is actuated for opening the pistol by the thumb of the right hand while holding the pistol as for firing. This is a great convenience—especially on horseback—as it enables the user to eject fired cases by the use of one hand only.

In the fore part of the pistol is an effective arrangement for causing the extractor to perform its function, and snap sharply back into its place. There is the ordinary lever of the tumbler type, having a ratchet tooth on which a small pawl catches, and holding the lever, causes the movement of the extractor as the pistol is opened. At the right moment a snail cam pushes the pawl out of gear, and the extractor is smartly flipped back into its place. It will be seen that all the above described mechanism is neat and well suited to the functions required.

Passing to the lock mechanism, by means of which the cylinder is rotated and locked, and the arm fired, we find safety and efficiency secured by a combination of limbs very few in number, but performing all the necessary functions. The limbs of the lock proper are only five in number (see Fig. 133), namely: The hammer (*b*), trigger (*c*), lifter (*d*), central lever (*e*), and mainspring (*a*). The following limbs used in other revolvers are dispensed with: The scear and scear spring, the catch and catch spring, the trigger spring and lifter spring.

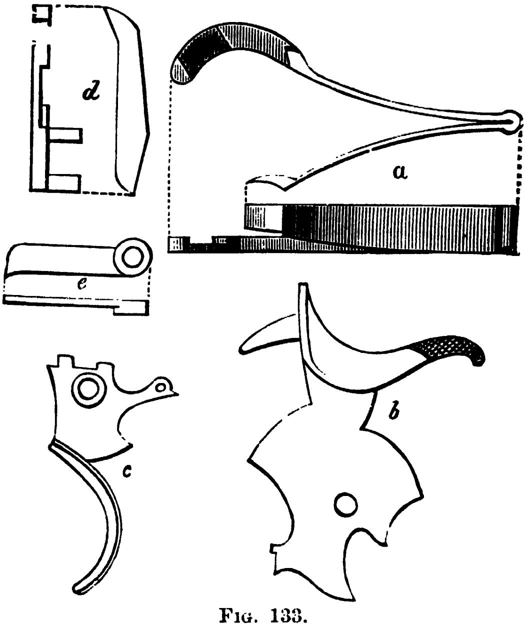

Fig. 133.

Therefore, when firing by means of the trigger action, the only resistances to be overcome are the elasticity of the mainspring and the very slight friction of the cylinder and limbs of the lock. Hence the trigger action of this pistol is lighter and smoother than that of any other, and closer shooting can be made with it. To understand the action of this lock it is necessary to thoroughly comprehend the peculiarities and functions of the mainspring. It will be seen that, while the play side of the mainspring performs the ordinary function of propelling the hammer against the cap, what is usually the stand side is set to do important work. Its extreme end bears on the central lever, and the central lever bears in a slot in the lifter, the lifter being also pivoted to the trigger. Hence this end of the mainspring plays the parts usually assigned to the scear spring, trigger spring, and lifter spring. Further than this, the lower end of the lifter passes under the toe of the hammer to perform the office of the ordinary catch; and, as this action is also due to the mainspring, no catch spring is required.

Somewhat further back on this limb of the mainspring is a step which bears on the heel of the hammer when the pistol is discharged and the trigger released, so bringing back the hammer to a position of safety, and locking it there.

When the pistol is shot with the trigger action the movements of the various limbs are as follows: The travel of the trigger raises the lifter, rotating the cylinder as usual. The lifter raises the central lever, and so compresses the under side of the mainspring, moving its safety projection sufficiently away from the heel of the hammer to allow a clear fall on to the cap. At the same time the lower end of the lifter, which is engaged with the toe of the hammer, performs the cocking of the hammer, and compresses the top limbs of the mainspring. As the trigger approaches the point of discharge a tooth on its upper side, a little behind its axis, engages with the cylinder and locks it for firing. At the point of discharge the lower end of the lifter slips from the toe of the hammer.

When the cocking action is used, the bent above the toe of the hammer engages with the scear nose on the trigger.

Complaints have been made from time to time that extracting revolvers have blown open when fired. With a well-made revolver such an accident can only happen by the inadvertence of the user; but, in great hurry on bad light, such inadvertence may happen to the most careful of men. Of course, when this accident happens the revolver is disabled by the bending of the spindle, and the consequent setting fast of the cylinder. To render such an accident impossible, Messrs. Webley and Son are now fitting their revolvers with Carter's Patent Safety Cylinder Locking Bolt. The construction is very simple, but the purpose served by it is very important in a revolver. In front of the usual trigger stop is this cylinder locking bolt. When the cylinder is stopped in the usual way by the trigger stop and the lifter, this cylinder locking bolt is operated by the fall of the hammer, and remains engaged with the cylinder until the hammer is again raised. The result is that the cylinder is doubly locked at the moment of discharge, *and remains locked during the return of the trigger,* and for whatever time may elapse until its next revolution. Amongst the advantages obtained are these:

The cylinder is always doubly locked for firing. It is locked during the return of the trigger and when the revolver is being carried, and an accidental displacement of the chambers is rendered impossible.

These two improvements are of great value, the first entirely doing away with the risk, attaching to jointed revolvers, of blowing open, and the second enabling a perfectly free cylinder to be used without any tendency to its going round too far, or turning back during the return motion of the trigger. The attainment of the free cylinder means securing that smoothness of action which is necessary for fine shooting with the trigger action, and, with revolvers so fitted, very nearly as good diagrams can be made with the trigger action as by the cocking.

The free cylinder spoken of is obtained in the Webley revolvers by means of the anti-friction nut. This nut is at the breech end of the cylinder, far removed from any liability of being affected by the fouling coming from the flash, and the cylinder is thus freely suspended on the centre spindle. The result is that, after long-continued firing, the cylinder revolves as freely as when the pistol is clean. Hence the pull on the trigger remains the same, no matter how many rounds may be fired; whereas, in revolvers not so fitted, the cylinder progressively increases its resistance, and the shooting becomes uncertain by reason of the ever-varying weight of pull on the trigger.

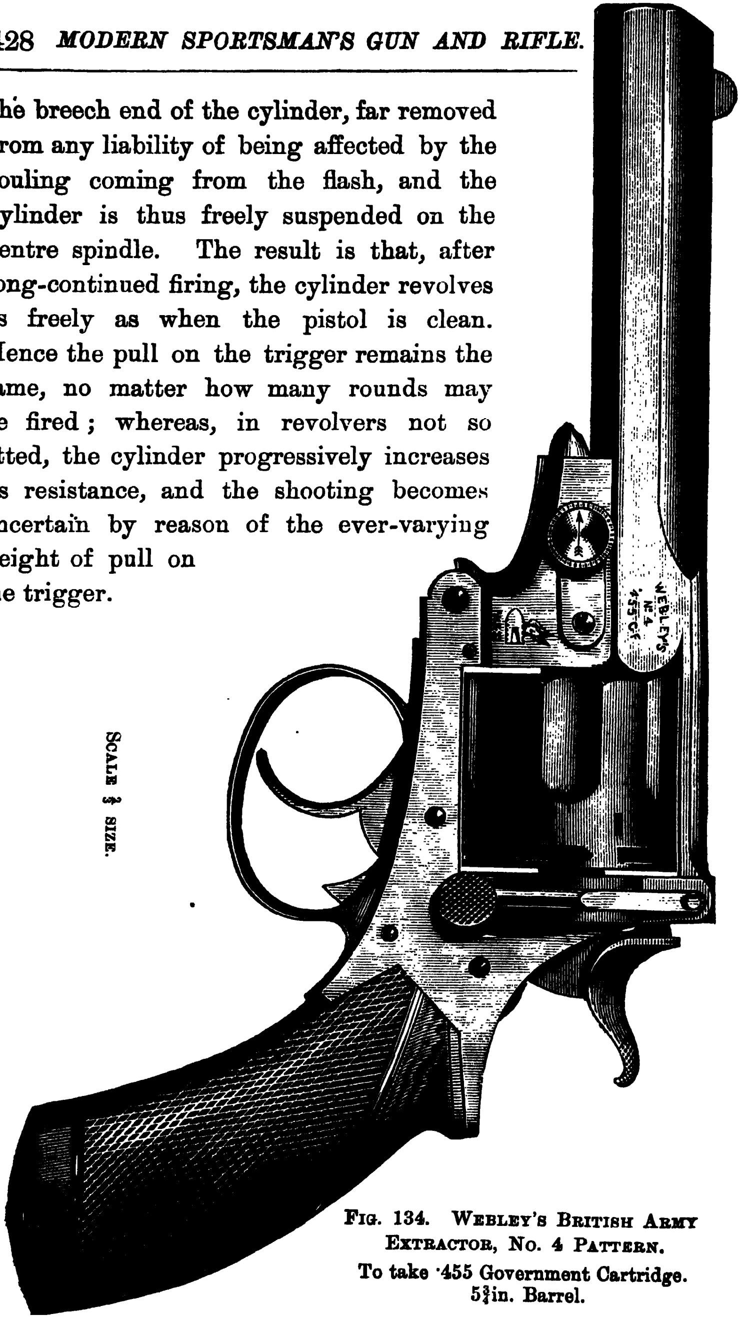

**Fig. 134. Webley's British Army Extractor, No. 4 Pattern.**
**To take ·455 Government Cartridge.**
**5¾in. Barrel.**

The Liege revolver, sold by Messrs. Bland at about half the cost of the corresponding Webley arm, is a good weapon at the price, but in material and finish will not compare with the English weapon, though rifled and finished in this

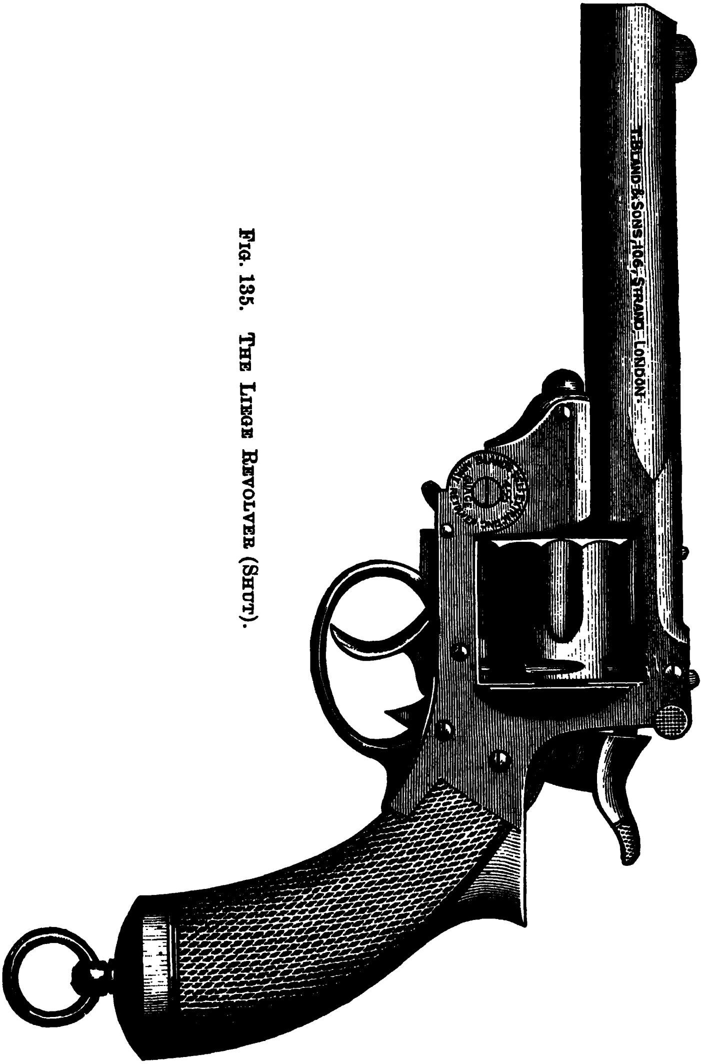
T. BLAND & SONS 106, STRAND, LONDON.

FIG. 135. THE LIEGE REVOLVER (SHUT).

country. I have made very good shooting with it, but not up to the form displayed by Mr. H. Webley and Mr. Ira Paine in the trials to be presently described. This was owing, no doubt, to some extent, to my having previously shot the Colt with the full charge of 40 grains powder, which had completely upset my shooting. To those who cannot afford the larger sum, this pistol may no doubt be a boon; but, irrespective of price, I should certainly advise the choice to be made between the work of Messrs. Webley and that of the Colt Company.

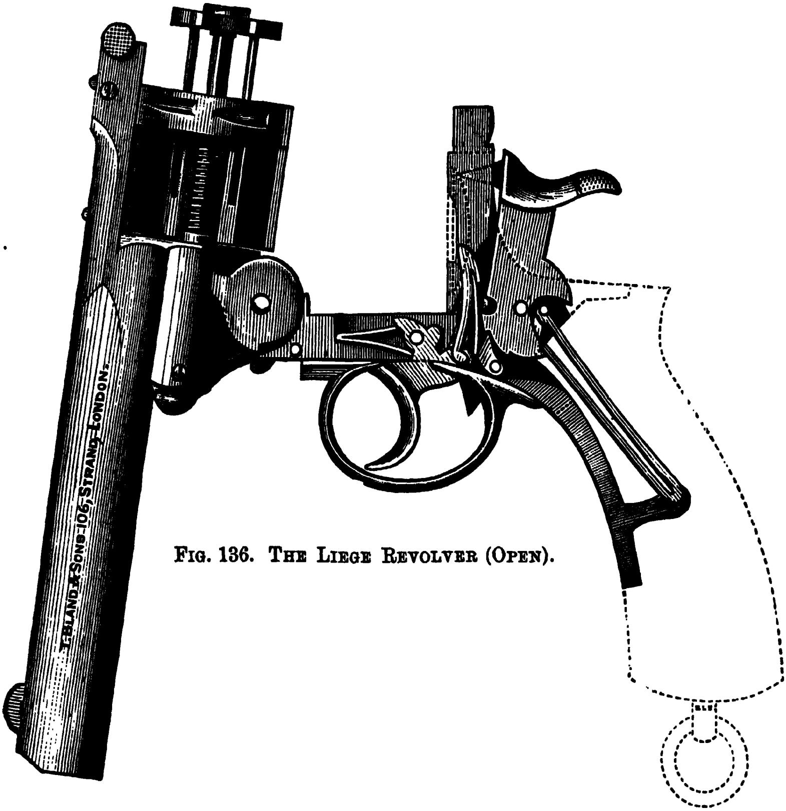

Fig. 136. The Liege Revolver (Open).

## TRIAL OF REVOLVERS.

In order to test the accuracy of the most prominent modern revolvers, I recently carried out a series of trials at Nunhead, in which Mr. H. Webley fired the new revolver of his firm at 12 and 25 yards, and, in competition with him, Mr. Ira Paine exhibited the powers of the Colt arms a fortnight afterwards, the weather on both days being all that could be desired. The following reports, written by myself, were published in the *Field*, and I now append them entire :

### TRIAL OF WEBLEY'S ARMY REVOLVER.

With a view to arrive at something like a standard of the shooting of the revolver, similar to that of the sporting rifle which we obtained at Putney last summer, we have lately seen several kinds tested in private, and have also shot some of them ourselves. Among these trials the best we have seen was the performance of an improved army revolver, made by Messrs. Webley, of Birmingham, with their new safety-bolt, which prevents the possibility of the action blowing open, inasmuch as, unless it is acted on by the closing of the top strap, the hammer cannot be pulled. In other respects the revolver resembles that described by us on the 10th of March last year (see Fig. 131).

By the courtesy of Mr. Brown, the proprietor of the Nunhead rifle range, we were permitted last Monday afternoon to use his fifty-yards ground at the back of his high butt, so that full safety from an erratic volunteer ball was insured. The weather being all that could be desired, Mr H. Webley duly appeared with the pistol, prepared to show its shooting for more than a hundred rounds without cleaning the action, and fifty rounds at twelve and twenty-five yards without wiping out the barrel, which intention he more than carried out, producing the excellent diagrams which we have since had engraved, and which at present we take to be the full standard of excellence, as far as our experience goes. His shooting with the trigger action is especially noticeable at twelve yards, but he did not come out so well at the longer range as might be expected. To produce this good shooting with the trigger action is a most difficult problem; but the object of the maker has been secured by a cylinder bearing, free in movement, steady, and safe from being clogged by the fouling of the escape backwards as well as forwards. In the Webley revolvers these three requirements are attained by the peculiar mode of, as it were, suspending the cylinder from the breech, and by the anti-friction nut. This mode of construction gives a remarkably smooth pull of the trigger, and enables first-class shooting to be achieved with the trigger action, while the cylinder remains free on its bearings after long-continued firing; at all events up to 200 rounds, to about which number we tested it.

Fig. 137 is a diagram of Mr. H. Webley's shooting at 12 yards, using the trigger action.

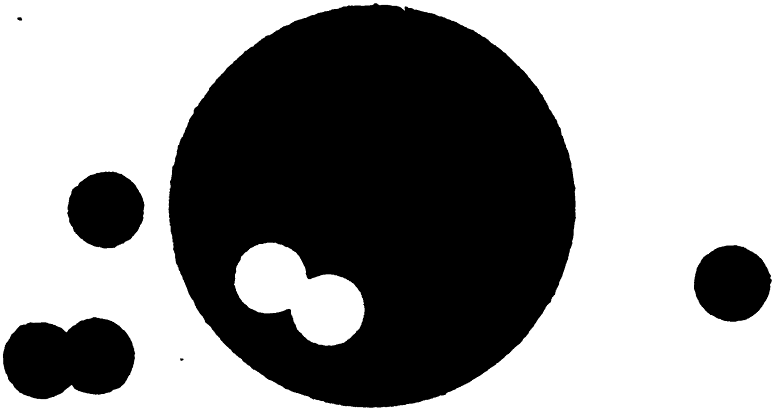

FIG. 137. TRIGGER ACTION, 12 YARDS, CLEAN.

Fig. 138 is the result of six shots with the cocked action at 12 yards. This, it will be seen, is not only not better than that with the trigger, but is a trifle worse.

Fig. 139 is by no means an average performance, and, as far as it goes, reverses the comparative shooting at 12 yards.

Fig. 140 is an extraordinary diagram considering the range, and is the best we have seen at the distance. We have ourselves obtained a diagram measuring 4½in. × 4in. at 18 yards, using the cocked action, but of course it will not at all compare with this of Mr. H. Webley professes to be able to make as good shooting with the trigger action as with the cocked pistol, and certainly the trigger cocking of his revolver is so smooth that one could almost expect it; but a public or semi-public trial does not

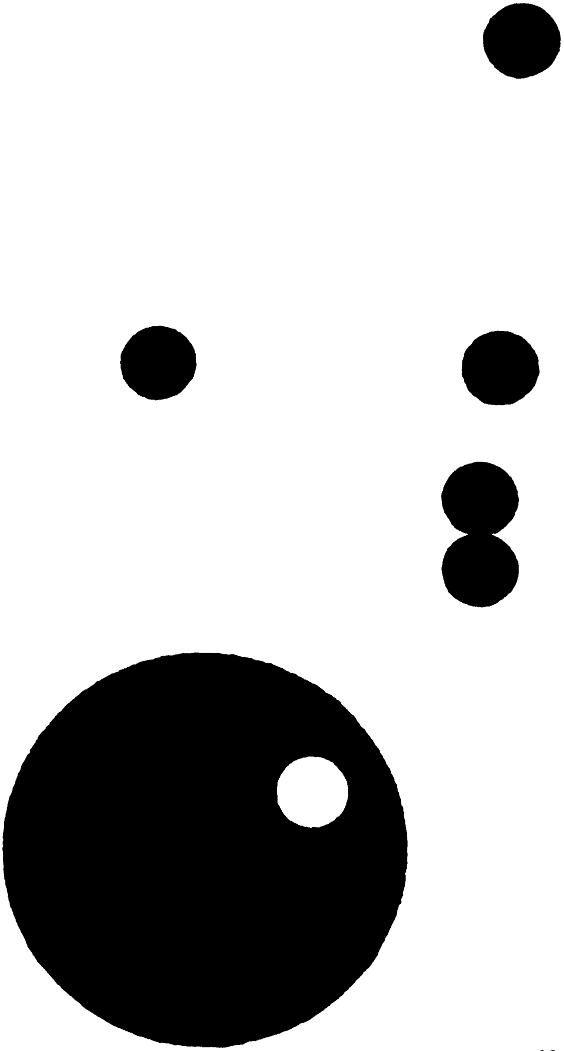

FIG. 138. COCKED ACTION, 12 ROUNDS, AFTER 6 SHOTS, AT 12 YARDS.

always come up to anticipation, and, though he fully realised his wishes at 12 yards, the contrast was very great at 25 yards.

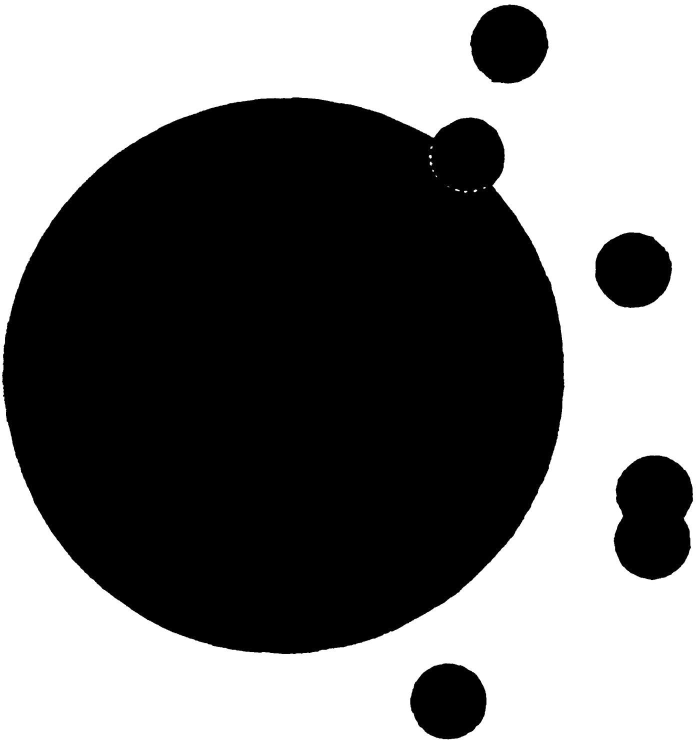

FIG. 140. COCKED ACTION AT 25 YARDS AFTER 24 SHOTS.

Having carried out the above experiments, Mr. H. Webley proposed to fire forty-eight shots as rapidly as possible, showing what may be done in a short time by the reloading of an extracting revolver, in conjunction with reasonable accuracy. Taking the loaded pistol, and having previously wiped out the barrel, but not even oiling the action, and with forty-two cartridges on a table by his side, he fired forty-eight shots at 12 yards in 3min. 5sec., producing the annexed diagram (see Fig. 141). When it is remembered that this cartridge will penetrate nine half-inch deal boards at 12 yards, this wonderful shooting shows what may be done by men only armed with revolvers if attacked at close quarters; and notably if the smoke could be prevented by the use of a smokeless powder, which we hope soon to see accomplished, even at the cost of diminished accuracy.

## TRIAL OF COLT'S REVOLVERS.

(From the *Field* of April 12.)

On Wednesday, April 9, we were present at a trial of the above at Nunhead, in the hands of the celebrated American pistol-shot, Mr. Ira Paine. On the average, they were about equal to those made by Mr. H. Webley, as reported by us on the 28th of March. His shooting at 12 yards was certainly better, but, though he had several trials, he did not come up to Mr. H. Webley's 25 yards diagram. At 50 yards the six shots made a square of 18in., or thereabouts, while at 100 yards twelve shots were barely within a space of 4ft. 6in. by 3ft. 6in. Curiously enough, Mr. Paine succeeded in firing forty-eight shots in 2min. 15sec., being 50sec. faster than Mr. H. Webley with his self-extractor, but his accuracy was not to be compared with that of the latter, the space covered being nearly four times as great. The actions all worked perfectly well, but the barrels of the pistols, several of which were used,

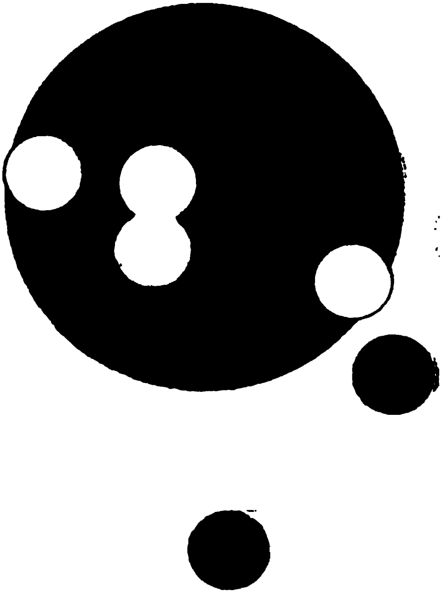

FIG. 142. ELEY'S CARTRIDGES, 12 YARDS, SHORT ARMY REVOLVER, 5½IN. BARREL, COCKED.

seemed to require considerable cleaning out with the rod, whereas Mr. H. Webley only used one pistol, and never cleaned out from first to last. In Mr. H. Webley's case only one diagram under each condition was made, with the exception of that consisting of 48

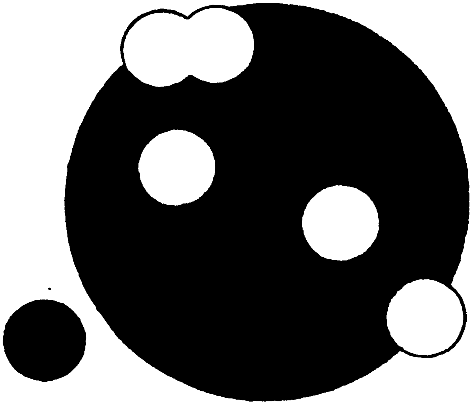

FIG. 143. 12 YARDS, SHORT ARMY, TRIGGER ACTION, ELEY'S CARTRIDGES.

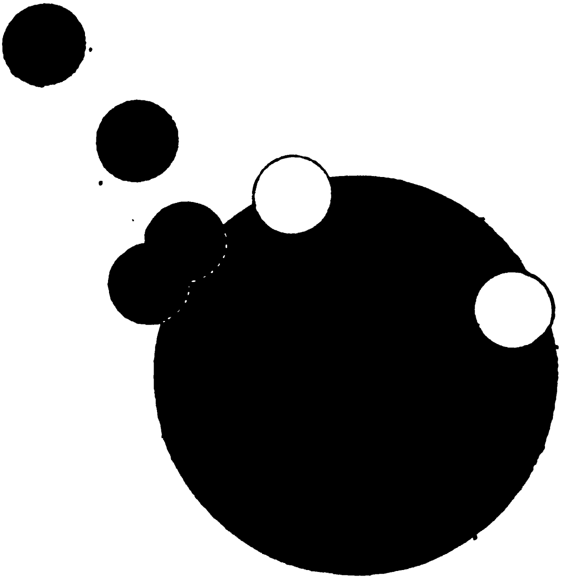

FIG. 144. 12 YARDS, SHORT ARMY, 7½IN. BARREL, ELEY'S CARTRIDGES, COCKED ACTION.

rounds at 12 yards, which was recommenced after about thirty shots, owing to the wind catching the edge of the paper, which was badly fastened, and destroying its texture altogether. Mr. Ira Paine, on the contrary, repeated his performance several times, sometimes with improvement, and at others in the reverse direction. In justice to Messrs. Webley, we have therefore taken the diagram first made in each case. Thus, Mr. Webley made only two diagrams at 12 yards, one with the trigger action, and the other with the cocked action, both of which we engraved. On the other hand, Mr. Ira Paine made six diagrams, viz., No. 1 with the short army regulation arm cocked (Fig. 142 in our engraved series); No. 2 was a diagram of the $7\frac{1}{2}$in. barrel (Fig. 144 in our series); No. 3 was a repetition of No. 2, which we do not give, but it is not nearly so good; No. 4 was another repetition of the same, and a very excellent one, all but one shot being within the 2in. bull; No. 5 was with the short army revolver, using the trigger action, which we give as Fig. 143, to contrast with Fig. 142, and is a very good one, quite equal to, or rather better than, No. 4 omitted; and, lastly, No. 10, which we give as Fig. 145, was made with the same pistol as No. 3, but using the American cartridge containing 40grs. powder and 200grs. lead. Undoubtedly the four diagrams we give above

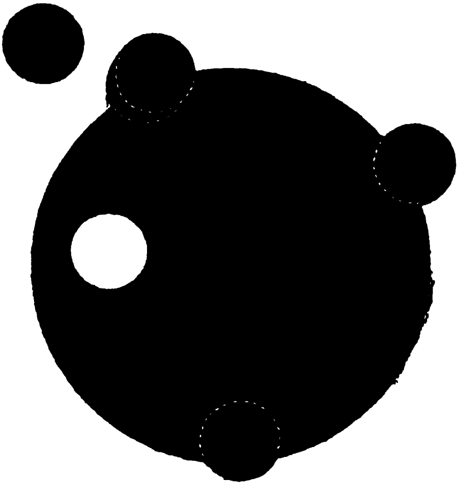

FIG. 145. 12 YARDS, 40GRS. POWDER, LONG BARREL, AMERICAN CARTRIDGES.

will compare favourably with Mr. H. Webley's performance at the same distance; but, on the other hand, out of six diagrams made by Mr. Ira Paine at 25 yards, not one will compare with that of Mr. Webley with the cocked action, which measured only 3¾in. by 1½in., whereas Mr. Ira Paine's first diagram (numbered now Fig. 146) measures 7¼in. by 4¼in., while his short pistol diagram, fired No. 8, which we now place as Fig. 147, measures 4½in. by 3½in. His diagram No. 7 measures 7¼in. by 7in. No. 9 measures 6½in. by 4in., No. 10 5¼in. by 2½in., and No. 11 8¼in. by 7½in. On the whole, therefore, it may be alleged that there is little or no difference between the two kinds of revolvers at these distances, assuming that the two performers are equal in skill, which we believe to be the case.

It will be remembered that Mr. Webley did not shoot at any distance beyond 25 yards, so that no comparison can be here made. We may, however, state that Mr. Ira Paine's diagrams at 50 yards vary from 7in. by 3in. to 12in. by 5in. At 100 yards, as we stated before, 12 shots were included in a parallelogram measuring 4ft. 6in. by 3ft. 6in.

As to the diagram made in rapidly firing 48 shots, Mr. Webley's is far the best, the whole being included in a space measuring 16in. by 13in., whereas Mr. Ira Paine's occupy a space 18½in. high by 16in. wide. This diagram was made with the short army pistol, using Eley's cartridges, and in the short space of 2min. 15sec. as against Mr. Webley's 3min. 5sec.

In conclusion, I may state that in describing all the revolvers mentioned in this chapter I have avoided any attempt to settle the claim to originality of invention; indeed, in some cases three or four patents have been combined into one perfect whole.

# CHAPTER II.

## NON-REVOLVING PISTOLS.

In order to avoid the escape at the junction between barrel and chamber, two or three kinds of four-barrelled pistols have been invented, in which the striker revolves instead of the chambers, by which means the cartridge can be inserted in the barrel itself. Among these an excellent one is that of C. Lancaster and Co., New Bond-street, which will be presently described. But before proceeding to the Lancaster pistol it will be necessary to note the fact that the germ of his invention is contained in the pistol invented about twenty years ago in America by Colonel Sharps, and long known as "Sharps' Triumph." In it, however, the revolving

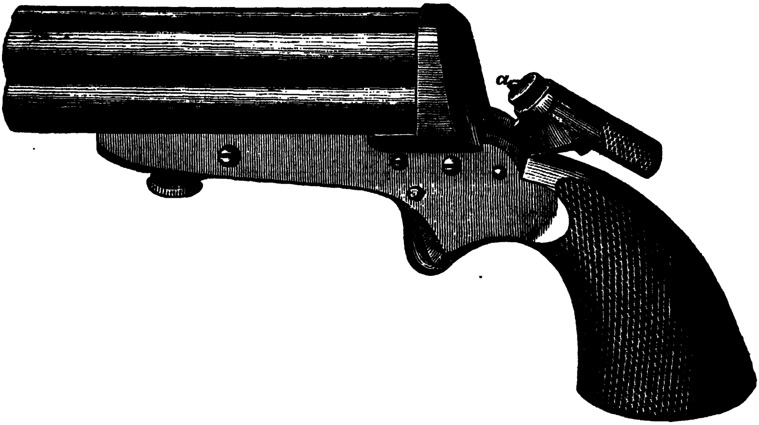

Fig. 148. Sharps' Triumph.

of the striker is effected by the working of the hammer, which is done by the thumb, as indeed was the case with all the revolvers of that day. The cartridge was of the "rim" kind, and the pistol (one of which, made at Birmingham twenty years ago, is now before me) is of course behind those of the present day. Fig. 148 gives an exact representation of it (two-thirds size), the revolving projection on the hammer being shown at *a*. The barrels slide forward from the "break off" for loading, and the empty cases are pushed back by a rod, in the usual way. We will now compare this original idea with the new plan worked out by C. Lancaster and Co., as described by the head of that firm :

### CHARLES LANCASTER'S PATENT FOUR-BARREL BREECHLOADING HAMMERLESS PISTOL.

This ingenious invention is constructed on the principle of the ordinary revolver, with this difference, that, instead of the chambers taking a turn before each discharge, a revolving cylinder with a striker attached is made to perform a similar office by the pull of the trigger, the said striker being brought to bear in turn on the centres of the four barrels, which are drilled out of the solid and machined so as to form a square, and which are hinged at the bottom, through which a cross-pin passes to keep them to the breech action on the lower side, and are fastened at the top by a projection when closed ready for use, which said projection is raised from the barrel by a lever placed on the left hand side, being the most convenient position, as the thumb, in passing the stock, readily works the lever to allow the connection to be lifted, and so cause the barrels to drop either for loading or unloading. The action of the lock is very simple, and is fully described in the *Field* of Jan. 14 and June 24, 1882, also in Vol. I. of present work, pp. 231-236.

The advantages which this new pistol possesses over the old form of revolver are, chiefly, increased accuracy and strength of shooting, owing to its dispensing with the escape between the revolving chambers and the stationary barrel, which not only acted prejudicially in the above directions, but made it impossible to rest the weapon on the left hand when aiming except at the risk of serious injury.

There is in this pistol no opening through which any gas can escape, so the weapon can be used like a gun when aiming (that is to say, with the left hand on the barrels); and there are no screws, hammers, or projections to catch the clothing, reins, &c.

Above all, there is no fear of a jam or the weapon becoming unserviceable from over heating or other accident. The mechanism is covered up, and dirt, damp, wet, and ill-usage hardly affect the pistol at all, as many officers who used them during the Egyptian campaign have testified.

The extractor is self-acting, and ejects all the fired cartridge cases at once.

The lock is rebounding, and the revolving cylinder and striker being jointed, there is no possibility of the striker protruding, thereby causing an accidental discharge, in the act of closing the barrels to the action. The lockwork is well made and is carried on metal, so that, should the stock become damaged, its perfect action is insured, the said stock only acting as a cover, no part of the said work being fastened to the stock (see Fig. 150).

These pistols are all rifled on Charles Lancaster's non-fouling smooth oval-bore system, thereby allowing shot to be used from them (as well as ball cartridges), from which very good practice is obtained up to 20 paces.

The four barrels are made to converge to a common centre at 40 yards, so that in aiming no allowance need be made to insure either of them covering the object in sight. They are made of the following sizes, viz.:

1. Full size, bore ·455 C.F.; total length of pistol, 12in.; length of barrels, 6in.; weight, 2lb. 8oz.

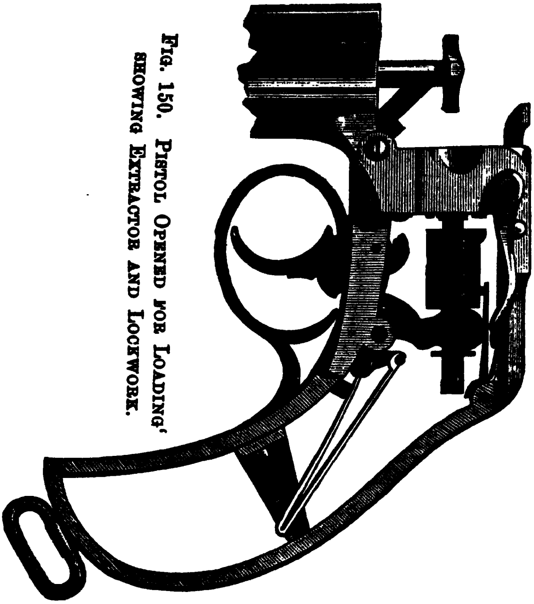

Fig. 150. Pistol Opened for Loading, showing Extractor and Lockwork.

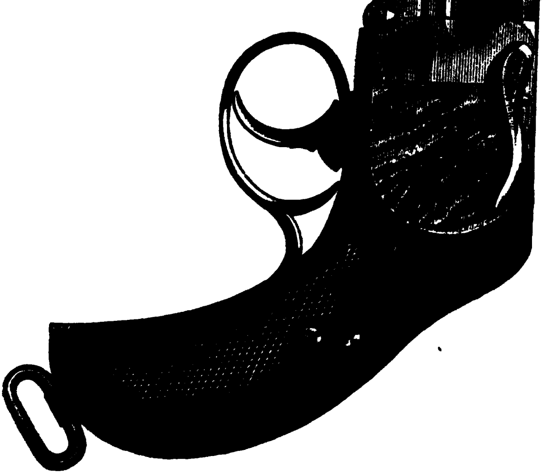

Fig. 149. Lancaster's Four-barrel Breech-loading Hammerless Pistol.

2. Medium size, bore ·380 C.F.; total length of pistol, 10in.; length of barrels, 5¼in.; weight, 1lb. 14oz.

3. Small size, bore ·380 C.F.; total length of pistol, 8in.; length of barrels, 3⅝in.; weight, 1lb. 9oz.

Full size takes the Government Regulation ·455 C.F. cartridge, and gave an average velocity of 970 ft.-s. at 75ft. from muzzle of pistol when tested at Messrs. Curtis and Harvey's Boulengé chronograph.

Medium size takes the ordinary rook rifle cartridge, ·380 C.F., Messrs. Eley's make.

Small size takes the ordinary revolver cartridge, ·380 C.F., Messrs. Eley's make.

These pistols can be supplied nickel plated to prevent rust.

Mr. Charles Lancaster has a new model in course of production, viz., first a 4-barrel B.L. hammerless pistol to take the ·577 revolver cartridge, and also double-barrel B.L. hammerless pistols constructed on the same principle.

Movable shoulder skeleton stocks can be fitted, which give a very great assistance where very accurate practice is required.

I have not tried this pistol myself, or seen it tried, but I have no reason to doubt that the admirable shooting with which it is credited by several correspondents of *The Field* is well founded, and, from the non-escape of gas, no doubt the initial velocity is greater than with the same cartridges fired from a revolver.

### SINGLE AND DOUBLE PISTOLS.

These are not now much in use in this country; but in America they are employed either for carrying in the pocket, or for saloon practice, or sometimes as a double-barrelled horse pistol, on the Lefaucheux principle, which is made of all sizes, and to take various kinds of ammunition. It is not much used in this country.

### THE SALOON PISTOL.

Long-barrelled (12in.) pistols, of very small bore, and with very shallow grooves, are made for use in the American shooting galleries. They are very accurate up to 30 yards, or thereabouts. With this pistol Mr. Ira Paine has for some time exhibited his skill and nerve, as well as the courage of his wife, by shooting at nuts, oranges, &c., on her head from a distance of 12 yards. Of course, this is nothing more than was formerly done with the smooth-bore duelling pistol with which in my young days every good shot could snuff a candle five times out of six at twelve paces; but no one ever heard of the most practised duellist exhibiting his skill by firing at an orange on the head of his wife. *Tempora mutantur*, however; and we must take the world as we find it. Knowing the uncertainty of the human eye and hand, my own opinion is that such exhibitions ought not to be allowed; indeed, the accident which happened to Mr. Ira Paine abroad, when his assistant lost a portion of his thumb, for which he obtained damages in England, shows that this opinion is well founded.

### THE DERINGER.

In America the most common form is the Deringer, as made by the Colt's Fire-arm Company. Its mechanism will be readily understood by reference to the annexed engraving (Fig. 151).

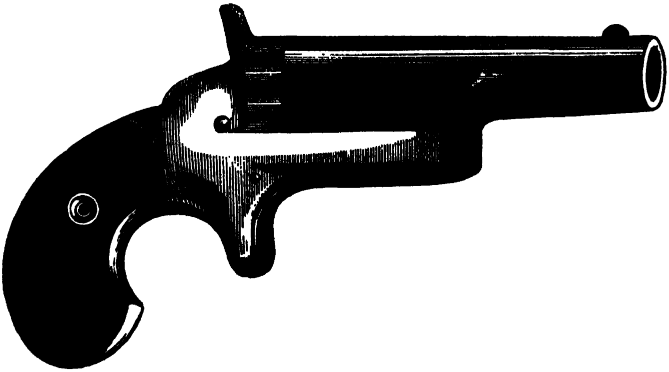

FIG. 151. COLT'S DERINGER.

# BOOK VII.

# THE MATCH OR TARGET RIFLE AND ITS AMMUNITION.

## CHAPTER I.

## INTRODUCTORY.

It will be readily conceded that one marked result of the Volunteer movement in this country has been that of familiarising a large proportion of our effective male population with the use of the rifle, mainly of course as a military arm. As a necessary outcome of the above state of things, the custom of shooting competitions and matches among riflemen has become quite general; and, independent of its value from a military point of view in bringing out the merits, both of the weapon and the shooter, there is no doubt that this class of shooting has attained the position of a recognised branch of sport; and, therefore, this work would be incomplete without some notice of the rifles, ammunition, &c., most generally approved of and in use for this purposes.

Though the term sport may be cavilled at as applied to rifle shooting matches, there can be no doubt whatever that most of the benefits to be derived from active out-door recreation with sufficient mental work and excitement to give it interest, are to be found in this pursuit as in all true sport: but the training obtainable in following what may be for the time a mere amusement, has in this particular matter a much more grave and important bearing upon our national ability for either attack or defence; since there can be no question that any nation that can venture to familiarise its sons with probably the most effective weapon the art of man has been able to devise, largely augments its fighting value against any assailant whatsoever.

The cultivation of an intimate acquaintance with the "bulls-eye" may lack the thrilling incidents of the tiger hunt, or the absorbing interest afforded by the protracted stalk of the red deer, but to a large and increasing class in this country it is exceedingly attractive; and, therefore, I think no further apology is needed for this section of the volume than perhaps may be conveyed in the following remarks made some century and a half ago by Robins, one of our earliest investigators into the mysteries of small arms. "I shall, therefore, close this paper with predicting that whatever state shall thoroughly comprehend the nature and advantages of rifled-barrel pieces, and, having facilitated and completed their construction, shall introduce into their army their general use, with a dexterity in the management of them, they will by this means acquire a superiority which will almost equal anything that has been done at any time by the particular excellence of any one kind of arms; and will, perhaps, fall but little short of the wonderful effects which histories relate to have been formerly produced by the first inventors of fire-arms."

I shall in this section of my work first consider the long range rifle with aperture sights that existed so long as a muzzle loader, and that is used for the highest class of rifle competitions, and known among riflemen as the "Any" rifle or "Match" rifle, *par excellence.* I shall then devote some little space to the more generally known army service rifle, following with an examination of the leading types of those rifles of a similar class known as M.B.L. or Military Breech-loaders, and shall conclude this branch of my subject with some remarks upon the proper manipulation of these rifles at the shooting range.

# CHAPTER II.

## HISTORY OF THE MODERN TARGET RIFLE.

I FIND it will be advisable and of assistance to my readers, in enabling them to fully understand the present state of the modern target rifle, if I depart from the rule observed in my treatment of both the shot-gun and sporting rifle, because in this case some account of the development of these weapons is almost indispensable before their present value as arms of precision can be fully realised. I therefore propose to give a slight sketch of the history of this class of arm from such a date as will not involve mere antiquarian research. This is necessarily given in a condensed form, but I have endeavoured to be as accurate in my statements as possible, though, through the rather imperfect form in which some of these interesting matters have been placed upon record, some slight amount of error, almost impossible to avoid, may have crept in. The chief authority consulted has been the annual reports of the National Rifle Association, a complete set of which from its commencement have been placed at my disposal. I have also availed myself of such other sources of information as will from time to time be found quoted in the margin. I trust the reader will find within the following pages as fair a statement of the origin and progress of the modern target rifle as it is possible now to obtain.

### 1852-3.

During this period was carried on a series of investigations that resulted in the production of the so-called Enfield rifle, elaborated from the best features of the existing Minié rifle and several other types designed by some of the leading gunmakers of the day.[*] The chief points arrived at seem to have been (*a*) a reduction in bore (from ·702 to ·577); (*b*) the use of a paper-covered elongated bullet, with a deep cavity in the base containing a plug or cup, which, being forced in by the blow of the explosion, expanded the bullet, and so caused it to engage with the rifling. (*c*) The fact that an odd number of grooves gave the best results with such a bullet, and that "grooves with only one side" (ratchet shaped?) were tried, but the experiments were not sufficiently exhaustive to enable any decided conclusions to be arrived at. (*d*) The depth of groove decided upon was at this early stage no less than ·014, or rather more than *double* the depth of the most approved modern styles, though this was subsequently modified, as will appear in due course. (*e*) Mr. C. Lancaster's contribution to this inquiry was an oval-bored rifle (since so intimately connected with his name); and, though this method of grooving was by no means novel, having been described in a work published about the beginning of the present century,[†] still it attracted some considerable amount of attention.

Along with this form of groove Mr. Lancaster adopted the American plan of a "gaining twist" or increasing spiral, together with a groove of varying or "progressive" depth, that is, deeper at the breech than at the muzzle, and in this particular model he used an exceedingly shallow grooving. No advantage in either accuracy or trajectory appeared in the trial of this rifle; on the contrary, a similarly grooved barrel, but with an uniform twist of spiral, gave rather better results.

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[*] Report of Experiments with Small Arms at Enfield. By the Hon. A. Gordon, Lieut.-Col. London, 1853.

[†] Scloppetaria. By Col. Beaufoy. London, 1808, pp. 87-88.

## 1854-7.

A gradual progress was made during this period, inasmuch as the Enfield rifle was the subject of improvement in details chiefly affecting the barrel and ammunition. The Lancaster rifle, too, was benefiting by a similar process. It is here that allusion may be made to the efforts of General Jacob toward the improvement of small arms in range and precision of fire. This gallant officer had experimented upon this question for a number of years, and had finally arrived at the conclusion that a plan involving the following details was calculated to give the most generally satisfactory results. A short barrel was preferred, 24in. only in length, of rather less calibre than the Enfield (·530 only), rifled with four deep grooves having the rapid twist (for the calibre) of one turn in 30 inches. The projectile used was a conical bullet (or shell), having a long and sharp point and four projecting wings or snugs on its cylindrical portion to engage with and fit the grooving. This plan never came into general use, the severe recoil and exceptionally high trajectory seriously discounting the fair degree of accuracy obtained.

This period is, however, most noticeable on account of its having been occupied by the experiments of Sir Joseph Whitworth, to whom must be ascribed the entire credit of having thus established the main principles upon which is founded every form of modern small bore rifle; his work will be found fully described at the end of this chapter.

## 1858-9.

No particularly marked step in the farther development of the rifle took place, excepting that gunmakers and others were busily engaged in inventing and perfecting rifles differing from the Whitworth, more or less, in points of detail, but, almost without exception, retaining the leading features of that weapon. About this time, several plans of breechloading rifles were introduced, all with the paper cartridge, and depending more or less upon a wad for rendering the breech gas-tight. These devices were all more or less short lived, excepting that of Mr. Westley Richards, which has existed down to recent times, though of course, since the introduction of the metallic cartridge, it has been forced into a subordinate position by the modern type of breechloader.

## 1860.

A most important chapter in the history of the rifle, was opened by the inauguration in this year of the National Rifle Association "for the encouragement of rifle corps and the promotion of rifle shooting throughout Great Britain," also "by establishing rifle shooting as a *national pastime* to make the rifle what the bow was in the days of the Plantagenets, the familiar weapon of those who stand forth in the defence of their country." That this admirable institution has had considerable influence, and generally of the happiest kind, upon all rifle matters is well known, and in fact the N.R.A., as it is familiarly called, has thoroughly identified itself with the history of target rifle shooting wherever the English language has penetrated. The chief winning scores at this meeting were made with Whitworth rifles, excepting in those cases where the competitors were restricted to the use of the Enfield rifle.

A rifle by Ingram, of Glasgow, with the ratchet shaped groove, and using a cylindrical hardened expanding bullet, secured a position in the prize list.* The B.L. rifle of Westley Richards, before alluded to, also made its mark on this occasion as on many subsequent ones, the barrel of this rifle was grooved on a modification of the Whitworth plan calculated to facilitate the use of a cylindrical bullet *not* mechanically fitting the grooves, as this latter arrangement is obviously unsuitable to a B.L. rifle.

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* *Volunteer Service Gazette*, Vol. XV., page 761.

## 1861.

At the N.R.A. meeting this year first appeared the since well-known "Henry" rifle, the grooving of which is shown on p. 251 of this volume. This modification of the Whitworth system was professedly brought out for the purpose of rendering the use of a cylindrical bullet less objectionable than it was with the Whitworth rifling, and to a great extent was successful, though the inventor, when requiring great accuracy, did not scruple to use a mechanically fitting projectile—so strong was the desire to profit by the researches of Sir Joseph. Subsequently Mr. Henry, by remodelling some of the details of his grooving, as pointed out on p. 252, succeeded in obtaining for his barrel considerable notoriety as a breechloader, and finally, as we shall see, its adoption for the service arm. Several other rifles by different makers, one of the most prominent being Mr. Turner, came into notice at this meeting, but no marked advance was perceptible. This year the first official notice of an improvement in the Enfield rifle that had been slowly arrived at during the previous years, appeared in the form of a statement by General Hay, and was to the effect that the modified groove was quite altered in its proportion; instead of being of one uniform depth from breech to muzzle of ·014 of an inch, it now was made ·015 deep at the breech end, diminishing to only ·005 at the muzzle. This is worth noting, as these proportions have held good to the present time, even through the change of the arm from the M.L. to the B.L. Snider.

## 1862.

The preliminary trials of rifles early in each season, first established by the N.R.A. in 1860, for the purpose of discovering the most accurate long-range arm wherewith to shoot the second stage of the Queen's Prize, had hitherto resulted in walks over by the Whitworth, but this year six competitors put in an appearance. Still the trial resulted in the Whitworth proving its superiority. It may be here remarked that the rifle submitted by Mr. J. Rigby, of Dublin, had ratchet-shaped grooves, and fired a cylindrical bullet. The leading small-bore prizes at the meeting fell to the Whitworth, the Henry rifle taking the next place.

## 1863.

Nothing remarkable took place this year, the Whitworth rifle still keeping to the front.

## 1864.

At the N.R.A. meetings of 1864 the position of the Whitworth rifle was unchanged; but at the preliminary trial of rifles early in the season Mr. Rigby succeeded in tieing the Whitworth upon the figure of merit obtained by the shooting of six rifles fired from the machine rest at 1000 yards range, a series of twenty shots being fired from each rifle, the mean deviation for both kinds of rifles being 1·83ft. Mr. Rigby had, however, laid aside during the previous season his cylindrical bullet, and had adopted a hard mechanically-fitting one, and also a different plan of rifling, offering, as it were, five ridges to the hold of the bullet. He had obtained some very good results in firing these rifles from my *Field* machine rest * (similar, in most respects, to the rest shown opposite p. 46, Vol. I.), so much so that at a subsequent trial in the autumn of this year he took the first place, and consequently obtained the order to supply the rifles to be used by the "sixty" in the "second stage Queen's" of the ensuing year.

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* This rest was devised by me in order to meet the objections made by several of Mr. Henry's friends and others to Mr. Whitworth's sliding rest, which, they alleged, was capable of manipulation by the sergeant in charge of it, either in favour of or against a competitor, by pressing on the butt of the rifle, and thus altering the line of aim. In those days, in the course of the twenty shots made for "figure of merit," a considerable fall took place towards the end owing to the fouling which accumulated in the grooves, and this, it was stated,

## 1865.

In the June of this year a trial of twenty of Mr. Rigby's rifles took place at Enfield. The shooting generally was very good, and one rifle gave a group of twenty shots at 1000 yards with a mean deviation of 1·11ft. only—a figure of merit never before reached by any rifle in a public trial. At the N.R.A. Meeting the shooting obtained by these rifles in the Queen's Prize was of a superior character to any hitherto obtained in this competition. The Whitworth rifle, however, still retained a prominent position in all competitions not restricted to the Enfield. The Metford plan of rifling first appeared at this meeting, Sir H. Halford using it in the Elcho Shield match. This weapon, destined to become a favourite arm for high-class long range shooting, was distinguished from its leading rivals by its designer having altogether abandoned the fitting projectile introduced by Sir J. Whitworth, and imitated in principle by nearly all the leading rifle makers. Mr. Metford took the smooth cylindrical bullet, such as was used by Mr. Henry, Mr. Ingram, and by Mr. Rigby in 1862, and, by making it of a hardened alloy (similiar to that adopted by Whitworth for his fitting projectiles, or perhaps not quite so hard) found that he could obtain fine results with it when fired from a barrel having its rifling groove of the same or even a less depth than that of the shallowest portion of the Enfield cut.

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could be counteracted by depressing the butt, which was held by the shoulder of the sergeant. My rest, on the contrary, was backed up by a spring (as it still is), and is therefore incapable of being tampered with. Having been present at all the early competitions held at Woolwich, my suspicions were certainly aroused, but I never had reason to believe that the great superiority shown by the Whitworth rifle up to 1864 was mainly due to this cause.

He further incorporated into his system the American plan of the increasing spiral, as Lancaster had endeavoured to do since 1852; and by further availing himself of every technical detail likely to prove of value, and insisting upon a high standard of workmanship, he was able to produce some very fine results, though doubtless a great portion of the success of the Metford rifling must be ascribed to the great improvement in the quality of the gunpowder used since 1854, when it was so imperfect that Sir J. Whitworth dare not rely upon it for any upset or expansion of the solid projectile he proposed to use.

## 1866.

Though the long ranges of the Queen's prize were shot with the Whitworth, a marked advance by the Metford rifle can be observed in the "Any rifle" competitions, and from this year may be dated the overthrow of rifles using fitting projectiles that obviously could not be used with breech-loaders, and, no doubt, if this type of projectile had continued longer in use, the advent of the B.L. rifle as an accurate long range arm would have been proportionately delayed.

## 1867.

This year Mr. Rigby introduced his model long range rifle, for which, in its essential features, he had adopted the lines that had guided Mr. Metford, as before stated, so much so as to cause some to consider Rigby as rather overlapping Metford in several respects. This is a matter I cannot undertake to discuss, but my readers will, no doubt, be able to arrive at their own conclusions upon the matter. These two rifles as M.L.'s will be found to have divided between them the larger proportion of the patronage and esteem of the long range shots of the country, and most deservedly so. This year may be considered as the starting point of the modern B.L. rifle, that is a rifle using metallic cartridges, carrying their own ignition as opposed to the earlier type of B.L. using consuming cartridges, and requiring a cap to be used with each discharge precisely as with a M.L. rifle. For the last seven years this latter style of B.L. rifles had been familiarly known at Wimbledon and similar gatherings; especially had the Westley Richard's "capping" B.L. distinguished itself by winning year after year the special prize for B.L. rifles given by the Duke of Cambridge, though the shooting made, as a rule, would not bear comparison with the contemporary shooting of the M.L. rifle now rapidly approaching perfection. One of the most successful of the new model B.L. rifles, introduced by Mr. Henry, now came decidedly to the front, and, as far as barrel and projectile, and to a certain extent, indeed, the entire weapon, was the precursor of the same details now embodied in the present service rifle, the Martini-Henry. The breech action adopted by Mr. Henry was, however, but a modification of the older and well-known American breech, known as "Sharp's," but somewhat re-modelled and adapted to the new conditions of cartridge, &c.

## 1868

Is only noticeable for the continued success of the shallow grooved cylindrical bullet M.L. rifles as against the older models. A number of B.L. rifles alike in most details affecting the shooting, but of differing mechanical arrangements in their breech actions, now appear, but no distinct advance can be recorded.

## 1869.

The investigations of the Government Committee on small arms, whose labours terminated in the selection of the Martini-Henry rifle as the service arm, caused a great impulse to be given to that class of rifle shooting, known as M.B.L. work, though at this period rapidity of fire was considered as well as accuracy ; the "Henry" barrel and ammunition being decidedly in the front. The "Any rifle" class of shooting calls for no remark, only that both the weapons and the shooters were steadily advancing to a high pitch of perfection. The Whitworth rifle was now nearly confined to the second stage Queen's prizes, scarcely appearing in the open competitions for small-bore rifles.

## 1870.

The newly adopted service arm, the M.H. rifle, comes to the front this year, the Duke of Cambridge's prize being won with one of these; though it should be noted that, up to and including this year, since 1863, the extreme range in this important competition has been only 800 yards, and the number of shots fired not exceeding seven, though the rifles used were supposed to previously qualify for rapidity and accuracy combined in a "time limit" shoot at shorter ranges. Nothing worthy of remark occurs affecting the fine M.L. rifles.

## 1871.

This year two new rifles were officially introduced to the rifle world. The Snider-Enfield B.L. replacing the Enfield M.L. arm, and the Government pattern Martini-Henry B.L. replacing the Whitworth M.L. in the second stage Queen's prizes, shot at 800, 900, and 1000 yards; thus M.L. rifles were swept away from the Wimbledon meeting in all but the fine long range "Any" rifles. The M.H., in all its essential features, had now settled to very nearly its present model. During its previous appearances at Wimbledon the rifle was heavier, chiefly in the barrel, and the long taper ·450 Boxer-Henry cartridge was used with it instead of the present pattern ·577-·450 bottled shape. The Metford barrel first appeared as a B.L. rifle at this meeting, and in combination with a falling block breech action of Westley Richards (on somewhat similar lines to the Martini breech), succeeded in taking the

Duke's prize, now for the first time shot for at the 1000 yards range, and hence justly considered the "blue ribbon" of the M.B.L. rifle at Wimbledon.

## 1872.

While the M.L. "Any" rifle continued in its finely developed form, some advance was made this year by the M.B.L. class of rifle—so much so as to cause a match to be shot between teams of five on each side, one armed with M.L. rifles, and the other with B.L. rifles, fitted with similar fine sights, &c., as used on the muzzle loaders. The conditions of the match were 30 shots per man at 1000yds. range. The M.L. team won easily, with a majority of 15 points per man over the scores made by their opponents, the shooting of these latter being of an exceedingly moderate character; four of these B.L. rifles had Metford barrels, and the other a Henry barrel. The "Duke's" was again won by a Metford-Westley-Richards, though a Henry rifle tied with the top scorer, and this latter rifle was very successful in the M.B.L. competitions now established, in which accuracy of fire alone was considered. As an illustration of the fine work the M.L. rifle was now capable of, Mr. E. Ross this year won the "Any rifle" Wimbledon Cup with a Metford rifle, the conditions being seven shots each at 600 and 1000 yards: he made all bullseyes at both distances.

## 1873.

The N.R.A. at this meeting gave a special series of prizes (the "Arthur") for the encouragement of B.L. "Any" rifles, the conditions being ten shots at 600yds., the B.L. not being considered as capable of fine work beyond this range. The majority of the prizes were won by the Swinburn and Henry rifles, the first prize being taken with one of the former weapons firing the Government M.H. cartridges, but with a barrel somewhat improved in the detail of the grooving as compared with the Henry barrel. Both these rifles were rather conspicuous in the open M.B.L. competitions, the latter securing the "Duke's" once more, the Metford W.R. being but moderately prominent in the prize lists among the B.L.'s. The perfection attained by the M.L. rifles calls for no remark this year.

## 1874.

The interesting competition for B.L. "Any" rifles at 600 yards, introduced last year, was this time won with a Metford rifle, after shooting a tie against a Swinburn. In the M.B.L. competitions the latter rifle, together with the Henry, still take the lead, though the "Duke's" was taken by a Metford B.L. with a score one point higher than that made by a Swinburn rifle with an Ingram barrel firing the Government M.H. cartridges. The breech action now used with the Metford barrel is the one invented by Mr. Farquharson and described in a succeeding chapter of this volume. This year may be considered to be nearly, if not quite, the climax of the success of the "Any" M.L. rifle as used for match and competitive shooting. In the autumn of this year took place the celebrated rifle match at Creedmoor, New York, between the Irish team, armed with Rigby M.L. and the American team armed with B.L. rifles of home manufacture, resulting in a defeat of the former by three marks only. The B.L. rifle used by the winners was of such a highly artificial and delicate construction that the barrel required to be elaborately wiped out perfectly clean between the shots, and only by strict attention was it enabled to overcome the M.L. rifle, which, of course, was fired continuously, though the scoring made by the latter rifles was fully up to the then best recorded work.

## 1875

The "Duke's" was again taken by a Metford rifle with a score one point higher than that of the second man who shot with a Henry—this latter rifle securing the first prize in the "Arthur," now a M.B.L. shoot; while the Swinburn took the first place in the "Secretary of State for War's" prizes, shot for at 900 yards. In general the M.B.L. prizes were pretty evenly divided among the three rifles mentioned. This year is memorable for the first appearance at Wimbledon of a small body of rifleman from the United States with their "Any" B.L. rifles on the swabbing out principle previously alluded to. Their shooting, though interesting, did not produce any immediately marked impression, though, by their again having defeated the Irish riflemen in the return match at Dublin, they had unquestionably proved the superiority (at least for mere target work) of their breechloader, used with a heavy charge of slow burning powder, and thoroughly wiped out after each shot, over our M.L. rifle, fired continuously without any other cleaning process than that effected by the well fitting wad passing down the barrel in the act of loading. From about this time British riflemen began to experiment first upon their M.L. rifles, carefully wiping them out between shots, and, farther, with B.L. rifles constructed on similar lines to those of the Americans (rifles of American manufacture being imported for the purpose), but for some time only modified success attended these experiments, as the powder in general use in this country was too rapid in its combustion to permit of the good points in this plan coming fairly out. In time this difficulty was of course got over, and a suitable powder manufactured. Another feature largely adopted from the American riflemen was that of using the "back" position in firing, though this position could not be considered a novelty upon Wimbledon common, as a few noted shots had fired in it for many years; still, the great success of the Americans in their matches attracted attention to its undoubted advantages, especially for long range work. A fine range score for this period was made in the Elcho Shield Match by Mr. Boyd, with an Ingram rifle M.L., at 1000 yards—he made in his fifteen shots, two magpies and thirteen bullseyes, finishing with eleven of the latter consecutively.

## 1876.

The performances of the "Any" rifle at the Wimbledon meeting of this year require no comment, except that the Great International Rifle Match took place at Creedmoor, New York. The match was contested by teams of eight men each from Ireland, Scotland, Australia, and Canada, with, of course, a United States team. The last-named won the match, which extended over two days, and was competed for under the usual Elcho Shield conditions. The Irish team came in a close second, still using the Rigby M.L. rifles. The remarkably fine shooting of a member of this team, Mr. J. K. Millner, at the 1000 yards range, is worth noting, it having never yet been equalled. Upon the second day of the match he made fifteen consecutive bullseyes at this distance, being the highest possible score; and, in a ten shot match a few days afterwards, he made ten consecutive bullseyes, thus again making the highest possible score. The "Duke's" was well won this year by the Metford B.L. rifle, no other weapon coming within four points of the winner's score, and a decided advance was made by the same rifle in the number of prizes won in the other M.B.L. competitions, more particularly in the "Sec. of State for War" and the "Henry," shot at 900 and 1000 yards respectively. In the shorter range competitions the other M.B.L. were more conspicuous.

## 1877.

The shooting of the winning team in the Elcho Shield match was this year exceptionally fine, they were armed (with one exception) with Rigby M.L. Rifles. Another important any rifle contest took place this year in the United States; and a team composed of riflemen selected from among the best shots of Great Britain and Ireland, tried conclusions with the Americans, and some fine shooting took place; but the visitors were beaten by a larger number of points than in any previous International match. There was now no doubt that the American cleaning-out system enabled breechloading rifles, so constructed as to suit this mode of treatment (and, indeed, to be useless without it), to give more accurate results in long range match firing than could be obtained from M.L. rifles. The B.L. competitions were largely won with Metford rifles—in fact, all the first prizes at the long ranges, except one at 800 yards, fell to this weapon.

## 1878.

This year the B.L. "Any" rifle began to make itself felt in the competitions established for these weapons, several leading riflemen using either imported American rifles or home-made weapons worked on the same plan; but in the Elcho Shield match the Irish team, all but one using the Rigby M.L., were again victorious with still more splendid scoring than that of the previous year. In this shoot is to be found the highest individual and collective scores ever made with the M.L. rifle in this country. It may be worth while to note that the habit of wiping out the M.L. rifle between the shots, now introduced in imitation of the American plan, no doubt contributed in some degree to these fine results.

In the M.B.L. competitions the superiority of the Metford rifle over the other types of B.L. rifles continued, though occasionally prizes were taken by the Henry and others.

## 1879.

Among the "Any" rifles at Wimbledon this year, the American rifles and their imitators showed increased prominence in the prize lists, no less than three of the former weapons being used among the English "Eight" and the "Albert"—the most important prize for this class of rifle was won for the first time by an American. In the M.B.L. shooting the Metford rifle was again very successful; but other rifles began to put in an appearance, among these the most noticeable are the Webley-Wyley and the Fraser, both described in a following chapter.

## 1880.

The M.L. "Any" rifle may be considered to be completely overpowered this year by the new style of manipulating the breechloader introduced by the Americans; and these latter show in the competitions open to them that, from some cause or other, the British B.L. rifles on their plan are unable at present to cope with them, nearly all the leading prizes for "Any" rifles falling to users of these weapons. However, the remarkably brilliant scoring of the Irish team in the Elcho Shield Match (all but one being armed with Rigby B.L. rifles on the American plan) shows conclusively that we were not far behind them in the dubious merit of producing such a useless type of weapon. The aggregate score of the Irish team upon this occasion is no less than 28 points in excess of their fine M.L. score in 1878. In the M.B.L. competitions the Metford rifle takes a prominent position, a sprinkling of prizes falling to the other rifles. Perhaps it is proper here to call attention to the almost total absence from the long range prize lists of the Government pattern Martini-Henry, and rifles carrying similar ammunition; this peculiarity may be noticed in the N.R.A. reports for the last few years, and is in itself most suggestive of the value of this class of weapon for accuracy of fire at the extreme ranges.

## 1881.

Again this year were the leading prizes in the "Any" rifle competitions taken by American rifles. In the M.B.L. competitions the Metford rifle met with a more qualified share of success than had fallen to its share during the few preceding years. For the first time since 1873 it failed to secure the Duke of Cambridge's prize, which fell to a Webley-Wyley rifle, the same weapon securing the first prize in the "Sec. of State for War" competition, shot for at 900 yards. In that important long range shoot, the "Bass," the first prize was secured by a "Fraser" rifle.

## 1882.

Though several leading prizes in the "Any" rifle shoots fell to American rifles, they were not so sweeping in their success as in the two previous years, probably owing to the fact that no visitors from the U.S.A. attended Wimbledon this year. In the M.B.L. competitions the Metford rifles retrieved their reputation, winning the first prize in every shoot, a proportion of the other prizes only falling to other rifles. This year took place the great International match between teams of British volunteers and U.S.A. National Guard. The match took place at Creedmoor, New York, and, either on account of our superior rifles or the superior shooting ability of our representatives, or most likely owing to both these points, we secured a somewhat easy victory, the weapons used being M.B.L. rifles (Metford's and Webley-Wyley's) by our men, and rifles of American manufacture by our opponents. The weather on the days of the match was not suitable for high scoring, consequently the figures do not show up well in comparison with the records obtained by both sides during practice, in which our men made some remarkably fine shooting, one man, Major Pearse, making 99 in a possible 105 at 800, 900, and 1000 yards, seven shots at each distance, firing with a Metford B.L. rifle. This fine score had, however, been previously reached by Corporal Bates, who had made 99 at the same distances in *competition* a short time before, using a Webley rifle.

## 1883.

The Council of the N.R.A., having at length realised the fact that the continued use of "Any" B.L. rifles worked on the American plan was prejudicial to the best interests of both rifle making and rifle shooting, resolved this year to prohibit the plan of wiping out between shots—thus putting an end to the practice. Their action in this respect met with almost universal approval from all true lovers of the rifle, the only regret being that so many years had been allowed to elapse before such a step had been found necessary.

They, however, rather weakly allowed the long obsolete M.L. rifle to still appear in these competitions. One result of this new arrangement was the almost total disappearance of the American rifles from the prize lists. In the M.B.L. competitions the Metford rifle was again successful, securing nearly every first prize, though, on three occasions a Webley, and once a Fraser, rifle take respectively the second place. A team of the U.S.A. National Guard attended Wimbledon for the purpose of shooting a return match with a team of our volunteers, similar to the match shot in the previous year at Creedmoor. This interesting shoot took place on the two last days of the meeting, finishing in most unfavourable weather, and resulting in a second defeat for the Americans, whose rifles and ammunition appeared to require such delicate manipulation as to show that they were undoubtedly inferior for all purposes to those in use by the home team.

For a number of years the shooting of the Government pattern M.H. rifle in the second stage of the Queen's Prize had been so remarkably erratic, particularly at the extreme range of 1000 yards, as to cause considerable dissatisfaction with the weapon among riflemen. In 1882 the shooting in this competition was of such a character as to require some steps to be taken to prevent for the future such a disgraceful exhibition as that afforded by the firing at 1000 yards on this occasion, in which considerably more than *half* the entire number of shots fired missed the targets. The Council of the N.R.A. determined to strike off the 1000 yards distance as beyond the powers of the weapon as far as accuracy of fire is concerned. Consequently this year, for the first time since the establishment of Her Majesty's prize, the "power and accuracy of English rifles and the skill of English volunteer riflemen" was *not* "shown to the world" at other long ranges than 800 and 900 yards. That a weapon costing so much to the nation, and specially designed and introduced as a long-range arm, should be the discreditable means of causing the conditions of so important a rifle competition to be altered and debased after existing for more than twenty years, is a fine commentary on the system by which such an arm was selected, manufactured, and foisted upon the nation.

Having now traced the shooting development of the present target rifle down to a recent period, I shall proceed to summarise the main steps in its progress to its present very perfect state.

It will be seen from the record I have been able to give my readers that in this country the rifle has progressed on dual lines since the production of the Enfield rifle or "large bore" on the one hand, and the "small bore," introduced by Whitworth, on the other hand. The former type of rifle has existed down to the present time (though now its continuance in the service can only be for a limited period) without any material improvement or modification other than that involved in the conversion of the M.L. form of this rifle to the Snider B.L., a slight change in the bullet from a paper wrapped one to a naked cannelured projectile well coated with wax, being the chief alteration, the internal details of the barrel and external form and arrangements of the arm remaining unaltered. The latter type of weapon, the "small bore," has passed through some most important stages before suffering the inevitable change from M.L. to B.L. Though presented to the rifle world in a most complete state, objection was taken to the form of projectile then supposed to be absolutely necessary to the display of the high degree of accuracy of fire undoubtedly possessed by this rifle at long ranges, even in its earliest days; and the important result that we may consider absolutely *depended* upon the substitution of the smooth cylindrical bullet (the possibility of the breech-loading system) for the mechanically fitting one justifies us in looking upon the introduction of the former projectile to the exclusion of the latter as a most important step. Like similar strides in other mechanical questions, it does not appear to have been wholly made or perfected by any one individual, though there can be no doubt that Mr. Metford has done perhaps more than any one else to perfect and popularise this now universally-adopted form of projectile. The introduction of the B.L. system to the small bore rifle has been a work of considerable time, and has moved with slow steps before arriving at the degree of perfection in accuracy of fire so early attained by the M.L. rifles of this class. A great proportion of this retardation of development has no doubt been caused, in the first place, by the weight of the Government example in adopting a defective form of cartridge shell, and so leading astray in this respect for some time both rifle makers and users; and in the second place, the pernicious effect upon legitimate long-range rifle manufacture of the hybrid American model B.L.

rifle, which had to be wiped out carefully between each two successive shots—a style of using a rifle so ridiculously absurd, that even the high degree of accuracy of fire so obtained could never justify the acceptance of such weapons by the general rifle user, though perhaps one step in the education of the public in rifle matters may in some degree be attributed to this type of rifle. Since 1864 it had become not only a fashion, but among a large and growing section of rifle shots a settled belief, that a rifle barrel to shoot at all accurately at long ranges must be grooved on the plan of an increasing spiral or varying twist. The dissemination of Mr. Metford's theories had largely to do with this notion; but the American rifles were, without exception, grooved with an *uniform* spiral of rapid pitch, and their shooting has proved beyond all doubt that the supposed excellences of the varying twist exist only in the imaginations of its advocates. We have fortunately quite got rid of the wiping-out nuisance, and the influence of the Government cartridge is practically *nil*, so we may now hope to advance and reach a still higher degree of perfection with what may be considered as our national weapon.

## THE WHITWORTH RIFLE.

Although now a matter belonging only to the history of the modern long range rifle, the weapon being itself obsolete, I cannot leave this portion of my subject without giving a short account of what is no doubt the most important step in rifle development that has been taken in the present century, or indeed in the history of these weapons.

In 1854 Sir J. Whitworth was applied to by the military authorities for his aid in investigating the mechanical principles involved in the construction of what was desired to be the most perfect rifle attainable for military purposes. The high position held in the mechanical world by this gentleman fully justified the application made to him, and one result was a grant of some 12,000*l.* or thereabouts made to him, for the purpose of enabling his experiments to be carried out in his own thoroughly exhaustive manner. As an illustration, one of his first steps was to erect a covered gallery 500 yards in length, 20ft. high and 16ft. wide, in which all the necessary firing could be carried on without any disturbance from atmospheric changes. He was restricted to a certain charge of powder, 70 grains (then unfortunately of inferior quality), and to a weight of bullet, 530 grains, and of course the weight of the complete arm was not to be materially different from the then average weight of such weapons, and less if possible. The main defects in the existing Enfield model rifle, viz., its high trajectory, susceptibility to wind influence, and defective accuracy at any but the shorter mid-ranges, he attacked in detail, proceeding step by step, until he proved that in every point the Enfield model was defective—in calibre, length of bullet, pitch of rifling, &c. Having decided to reduce the calibre from ·577 to ·450, his researches into the question of pitch or twist of rifling were carried out so thoroughly that he experimented on barrels rifled with every degree of spiral, in variations of 5in. from the Enfield twist of one turn in 78in. to *one turn in* 1*in.*, and in this way exhausted the subject, and arrived at the conclusion that the best twist for a rifled musket is one turn in 20in., the bore being ·450. This construction he ascertained to give the best results with the charge of powder and weight of bullet, and weight of arm. To such he was limited, but he distinctly states that if any modification was necessary it would be in the direction of a rather more rapid degree of spiral. It will be seen that by retaining the same weight of bullet as the Enfield in a much smaller calibre, the projectile must be much increased in length. This is the case, and is a most important feature in the Whitworth system; indeed, he says: "I have always contended that the primary element of success in long range shooting is *length of* *bullet,"* necessitating, of course, quick rotation, to insure accuracy.

The conclusions arrived at in these experiments have not in any material point been improved upon since their first publication, and every variety of small bore rifle is based upon Whitworth's proportions in these particulars. The one detail that has since been overthrown is the mode of rifling or grooving the interior of the Whitworth barrel, and his plan of mechanically shaping his bullet to fit it. There can be no doubt that this mode of construction was adopted mainly in consequence of the poor quality of the service powder originally supplied to Whitworth, which he describes as the "siftings of the cannon powder,"* and was wholly unequal to the work of expanding or upsetting the bullet in an uniform and reliable manner; by securing the engagement of the bullet and the rifling mechanically, this difficulty was overcome, and a fruitful source of wild shooting done away with.

Another feature at that time highly thought of in connection with mechanically fitting bullets was the opportunity afforded of using extremely hard projectiles, and so obtaining a great amount of penetration. Bullets of hardened and tempered steel have been fired from an ordinary Whitworth rifle, at an angle of 45 degrees, through a half-inch iron plate, punching out a clear hexagonally-shaped hole; such work cannot, of course, be obtained from any of the modern plans of grooved rifling firing smooth cylindrical bullets. The first objection urged against this combination was the expense of the ammunition; and to meet this a cylindrical bullet was introduced; but the accuracy of fire when these were used was considerably reduced, it being some 15 per cent. less than with the mechanically fitting bullets. As has been stated, it was soon discovered that better results with the cylindrical bullet could be obtained if other than the Whitworth plan of rifling were used; thus the modern methods arose, and the advent of the breech-loader made possible, which would never have been the case while fitting projectiles were considered indispensable. It can be easily understood that, having met with such a decided success at the earliest stage of the introduction of his plan of rifle and ammunition to the shooting world, Sir J. Whitworth was exceedingly unwilling to lay aside what had produced such magnificent results, and therefore did not modify those details in his arrangements that grew out of accord with the progressive spirit of the times; though, as late as 1876, he produced a B.L. rifle upon a modification of his plan, having an increased number of grooves, and still retaining the fitting projectile, whose use in a B.L. rifle required a complication in the form of cartridge and chamber recess that was found to be of no equivalent value. In addition to those principles that form the foundation of long-range rifle construction, for which we are indebted to Whitworth, this branch of manufacture has permanently benefited by the highly accurate and superior tools and processes introduced by him, for, until he became interested in the question, there was no proper system of sizes nor accurate measurements employed in those details of rifles that subsequent experience has proved to depend entirely upon extreme correctness of proportion for the accuracy of fire obtainable from the weapon. Indeed, when we come to consider the great and unmistakeable advantages that have accrued to the nation in consequence, it will be readily conceded that very rarely has public money been laid out to better purposes than in the grant to Whitworth thirty years ago.

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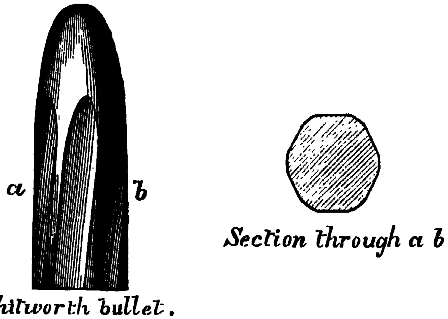
* **Report of Committee on B. L. Rifles. London, 1869.**

As a record of what amount of accuracy of fire the Whitworth rifle was capable, I may state that a diagram has been obtained at the 500 yards range with a mean deviation of 3·25 inches; and at the 1000 yards range a mean deviation of 10·5 inches; in each case a series of 20 shots constituted the group. The annexed figures show views of the Whitworth mechanically fitting bullet, and an enlarged section of a barrel showing the plan of grooving; the bullet is divested of its paper jacket.



Whitworth bullet.

Section through a b

FIG. 152.

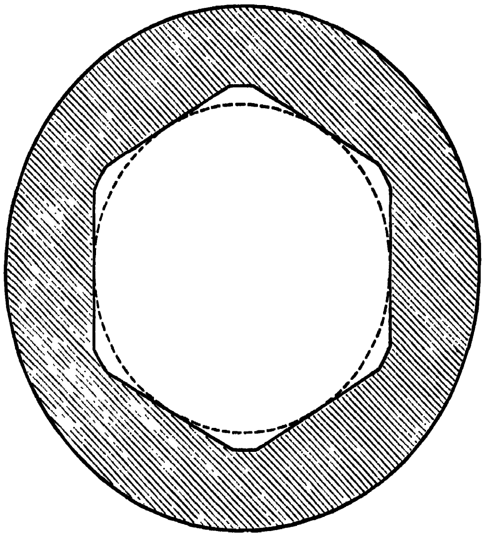


FIG. 153. WHITWORTH RIFLING (ENLARGED).

# CHAPTER III.

## THE "ANY RIFLE" AS USED FOR MATCH SHOOTING.

HAD the subject-matter of this chapter to be considered a year or two ago the varieties of rifle then existing, and coming under the head of "Any" rifle, as defined by the N.R.A. conditions for the regulation of the Wimbledon Meeting, would have been so numerous as to have required some large amount of space for their due treatment; but as the effect of recent legislation by the council of the N.R.A. has been to practically narrow the "Any" rifle down to what may be considered as a superior kind of M.B.L. rifle, I shall confine myself to enlarging upon those points in which the present B.L. "Any" rifle differs from that weapon. As to the M.L. rifles, though their use is still permitted, I shall consider them as obsolete, which they undoubtedly are as far as the modern sportsman is concerned. The "Any," or Match rifle in its present form is a B.L. rifle that must be fired *continuously*, that is to say without wiping out or cleaning between shots; it may be 10lb. in weight, or three-quarters of a pound heavier than the ordinary M.B.L., a point in its favour, as a heavier bullet may be fired without any corresponding increase in recoil being felt by the firer. This rifle may also have the pistol grip, a shape of stock not permitted in a military rifle for some abstruse reason or other, though, as we have seen in treating upon sporting rifles, it is always used in these latter weapons; but the characteristic feature in this class of rifle is the elaborate sights that are permitted to be used upon them. These sights, called "Aperture" or "Orthoptic" sights, are the outcome of considerable ingenuity on the part of gunmakers and others, and were probably never contemplated when the career of the "Any" rifle, as distinguished from the ordinary Military arm, was commenced, in fact we find in the earlier Reports of the N.R.A., several complaints upon this score. Still, there can be no doubt that sights of this kind are a great advance upon ordinary "open" sights, as far at least as in localising the aim, though it appears that to bring out their full value the weapon with which they are used must be capable of discharge with the minimum of muscular exertion, as, without an abnormally light trigger pull, the fine adjustment of aim these sights permit cannot be utilised. Whether it is advisable to continue and encourage the use of a class of weapon having such sighting arrangements as to require so light a trigger action as to be positively unsafe in ordinary use, is a question that deserves consideration, though probably an objection of equal value could be raised against the sights themselves as too delicate for any ordinary use, and, therefore, possessing that unnecessary artificiality which it is desirable to banish from so practical a tool as a modern rifle should be. The tendency, however, of modern progress in this particular has been slightly in the direction of simplifying these details, but, the difference in practical utility between the ordinary M.B.L. and the Match rifle is so markedly in favour of the former, and the superiority of the latter in point of mere accuracy is so slight, that we are justified in looking forward to the time when the Match or "Any" rifle, with its *impedimenta,* will be completely replaced by its more generally useful and more widely appreciated rival. It is quite true that long range rifle shooting would not have arrived at its present pitch of perfection if it had not been for the work done in the past by the Match rifle and its devotees; and a similar remark would apply to other matters in the rifle world now gone and past.

That the experimentalist will always avail himself of every contrivance calculated to further his researches we may be quite sure, but that is no reason why a type of rifle, purely experimental, and of no possibly practical use in the field, should continue to be allowed in public competitions, such as at Wimbledon, to the detriment of other more useful and popular weapons.

The method of aiming with rifle sights through holes or apertures instead of open notches is of some considerable antiquity, and various devices for this purpose will be found fully described and illustrated in that ingenious old work "Scloppetaria," in the chapter on sights, pp. 124 to 150.

The modern form of aperture sights, both back and front, first appeared on the match model of the Whitworth rifles about 1861, and the credit of their re-introduction must be shared by Lord Vernon and Mr. Leece. There have been endless variations in form and detail, but the main features in these sights as now used is as follows: A circular screen or eye-piece of such a size as to shut out nearly all extraneous objects when the eye is applied sufficiently close to it for a proper aim to be taken through a small pin hole or aperture in the centre of the screen. This hole varies in size in different specimens according to the fancy of the user, or perhaps in proportion to the distance he is in the habit of maintaining between his eye and the screen when using the same, a small hole answering if the eye is closely applied, and a larger being necessary if the eye be farther removed, the same sized field of view being retained. This screen is mounted upon a slide, having some inches of vertical movement upon the sight leaf controlled by a screw, and capable of being set to a minute degree of accuracy by means of a graduated scale generally furnished with a vernier to facilitate adjustment. The leaf is mounted upon a strong hinge joint, and forms what is called the "back aperture sight," specimens of which are shown on the folding sheet of figures accompanying this page at Figs 158 and 160. The front aperture sight is of various forms to suit individual tastes and the exigencies of changes in light, &c. At one time a large variety of these different patterns was in use, but of late the general tastes seem to have settled upon the above: These, in various sizes adapted to the varying size of the bullseye as seen from the different ranges, are now considered sufficient for all purposes.

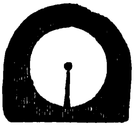


FIG. 161.
SOLID BEAD.

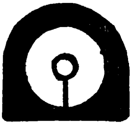


FIG. 162.
HOLLOW BEAD.

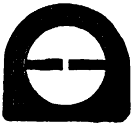


FIG. 163.
CALLIPER.

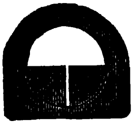


FIG. 164.
SPLIT BAR.

These front apertures or diaphragms, as they are sometimes called, can be fitted at will into a holder or shade that is mounted upon a slide having a small amount of lateral motion, for the purpose of compensating for the wind allowance that may be required; in addition, a spirit level is affixed, for the purpose of checking the position of the rifle from shot to shot, which can by this means be easily done while aiming. Two specimens of these sights are shown upon the annexed sheet at Figs. 157 and 159, one showing the wind gauge scale to the front, and the other a view from the near or aiming side, showing the spirit level; this sight, as is shown in the illustrations of match rifles, is attached near the muzzle of the rifle, the back sight being almost invariably fixed near the heel of the butt. In this way a considerable distance is secured between the two sights, facilitating their alignment. The method of using these sights when they are properly affixed to the rifle is as follows: the user adjusts, by means of the vertical scale on the back sight, the angle of elevation of the arm to the desired amount required by the range at which he is about to fire; then, by a similar lateral adjustment of the front sight, he compensates for the effect upon his bullet of any side wind there may be blowing; then, getting into a suitable position (with rifles whose sights are fitted as shown in the figures, the back position is of course imperative) he brings his eye to the small pin hole in the screen of the back sight, when his field of view is restricted to a small proportion of the landscape, the central point of which is, of course, the target with its bullseye. Supposing him to have the hollow bead front-sight, he then encircles or frames the bullseye with the ring of the sight, at the same time centering the whole in his field of view. In this he is assisted by the circular form of the front sight shade or holder. When all is duly concentric his aim is perfect, and he may venture to fire. It will be easily understood that some considerable practice is required before these sights can be fully utilised, and indeed the whole manipulation involved is of a most special and delicate character if the very highest results are to be obtained.

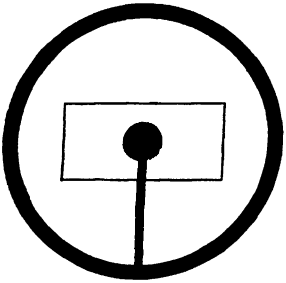


FIG. 165. SOLID BEAD.

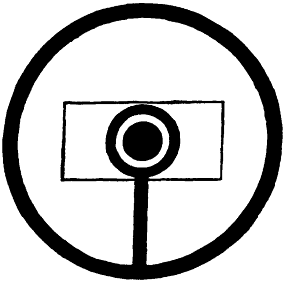


FIG. 166. HOLLOW BEAD.

The annexed illustrations will give some idea of the appearance of the target when aiming with each pattern of the fore sights I have illustrated. Fig. 165 shows that when the "solid bead" is used, the bead should be of such a size as to enable us to conceal the bullseye, by covering it with the sight itself. This may seem rather a vague style of aiming, but that the eye is able to accurately carry out this method is shown by the fine work accomplished by men who use this sight as a rule in preference to any other. For example, Capt. P. T. Godsal, whose shooting for some years at Wimbledon has been of the highest character, invariably uses this sight.

When the ordinary size of hollow bead is used the bullseye is shown framed, as in Fig. 166, and this sight is a general favourite; but a fine light is absolutely necessary for its successful use with most persons.

Some years ago the use of a very large sized hollow bead was introduced by a well-known shot in the North of Ireland, the appearance of which upon the target is as in Fig. 167.

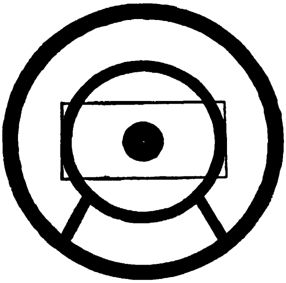


Fig. 167. Large Hollow Bead.

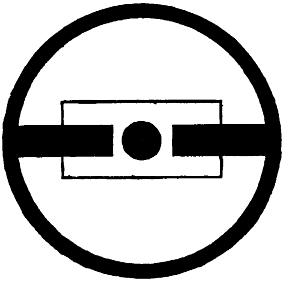


Fig. 168. Calliper.

It would be scarcely thought possible that really fine work could be done with such a sight, but to those accustomed to its use there appears to be no difficulty in fine scoring. The actual size of the hoop or ring approaches ·2 in diameter, and looks so huge as a sight that one of the mild jokes current among rifle shots arose from the fact that on one occasion, when a member of the English Eight, of rather slight physical proportions, was observed using such a sight, some one remarked "What on earth does D—— want with such a sight as that?" The reply was "Oh, when he has finished shooting he amuses himself by crawling backwards and forwards through the hoop."

The calliper sight exhibits the appearance as in Fig. 168.

This sight is an exceedingly rigorous test of steadiness, as the slightest pulsation causes the points to appear to be alternately thrust into the bullseye.

The split-bar is generally used as shown in Fig. 169, though some who use this sight largely have a semi-circular depression to fit the bullseye in addition to the split or daylight line.

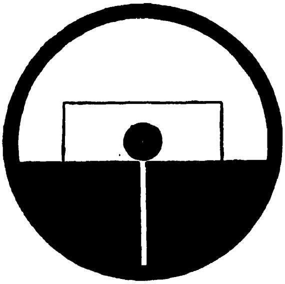


FIG. 169. SPLIT BAR.

In addition to the forms of sights of this class already illustrated I give what is considered to be a model embracing several improvements, manufactured by Messrs. D. and J. Fraser, of Edinburgh, and invariably fitted to their target-rifles, as will be shown in due course.

It will be seen from the illustration of the back sight here given that the mode of raising and lowering the slide carrying the eye-piece is very different from the usual method employed; not that this arrangement is wholly novel, having been introduced in the sights used upon the American "Sharps" model rifles. Instead of the long thin draw screw this slide is controlled by a short screw of large diameter having for its female screw each side of the main vertical slot in the leaf. The screw itself is deeply marked upon its periphery by vertical lines dividing its circumference into a series of parts, so that when this is moved by the fingers the amount of lateral motion shown by one of these divisions on the screw indicates that the eye-piece has received a minute amount of vertical movement. Upon the outer edge of the leaf is marked the coarser graduations required, without any vernier scale arrangement, the place of which has been effectively supplied by the divisions upon the screw itself. It will be noted (see Fig. 170) that the eye-piece of this sight is much smaller in diameter than in the other specimens shown, but this can be remedied if found necessary by fixing on an indiarubber cup of any required size, an expedient indeed often resorted to with those sights having eye-pieces of ordinary pattern, as thus the eye of the firer can be placed quite close to the sight without risk of receiving a blow from the recoil of the piece during firing. This back sight is usually mounted upon the rifle in such a manner as not to require taking off at the conclusion of practice, and re-fixing before commencing firing. For this purpose a trough or cavity is made in the "comb" or upper edge of the butt, in which the sight drops when folded down, and in which it is securely protected from damage.

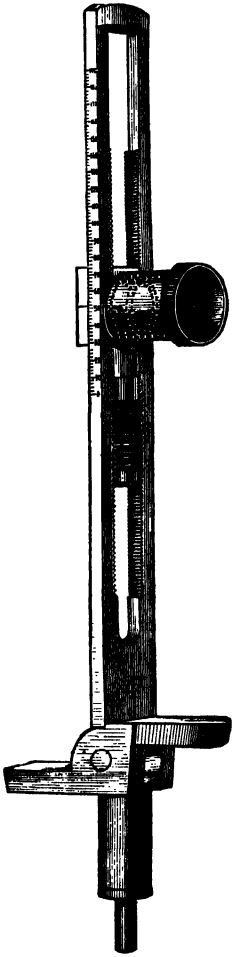


FIG. 170. FRASER'S BACK SIGHT.

The front sight offers no very remarkable features of difference from that of the ordinary pattern, other than the arrangement of spirit level, which in this case is let into the shade or body of the sight, instead of being attached in front as usual. The field of view is also much larger in this construction, though these modifications throw the line of sight somewhat higher above the axis of the barrel than is the case with the sights of the ordinary pattern. The tubular shade (Fig. 172), capable of attachment either on the near or far side of the sight, according as the sun may be at the back or in front of the firer, is no doubt a most useful feature, and one of great value to the rifleman.

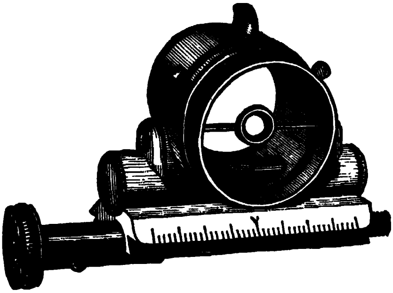


FIG. 171. FRASER'S FORE SIGHT.

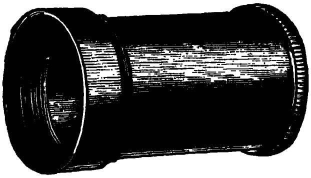


FIG. 172. FRASER'S TUBULAR SHADE.

## THE VARIOUS KINDS OF DIVISIONS OR SCALES UPON APERTURE SIGHTS.

Owing to the differing views of rifle makers and others connected with the manufacture and use of rifles having these sights attached, several styles of scales have been adopted for the purpose of registering the amount of elevation employed with the rifle at any given distance, and also to enable the firer to make any required alteration in a simple and easily understood manner; the conditions involved in rifle shooting not permitting the mind of the operator to be employed in abstruse considerations, as his attention is generally fully occupied in observing and combating external antagonistic influences. The one constant value to be considered mainly in the construction of such a scale is the distance between the front and back sights; and it is found that if this be taken as the radius of a great circle, and a scale marked upon the back-sight (actually a tangent to this circle) whose smaller values as given by a vernier are equal to *minutes* of this circle, such a scale will have two advantageous features, (*a*) it will not be too fine, to offend the eye—as rifles are usually made; and (*b*) it will give definite and easily remembered equivalent values upon the target for each and every range fired at. It is not necessary here for me to give a description of P. Vernier's ingenious arrangement for sub-dividing the larger divisions of a scale, as such an explanation can be found in several of the works upon such subjects,* though it is a matter quite necessary for every rifleman to master. When, as in the old pattern match rifles (with the back sight fixed upon the grip), the sights are three feet apart, one-hundredth of an inch upon the back sight is practically equal to one minute of angle, therefore such sights were so divided as to give upon their verniers ·01, whose equivalent value upon the target was *as many inches as the range fired at is in hundreds of yards*; for instance, 1in. at 100 yards, 2in. at 200 yards, 5in. at 500 yards, &c. Though rifles are seldom now made with these sights three feet apart, the same rule holds good in all cases; but the scale upon the back sight has to be modified, that is to say, made coarser if the sights are wide apart, and finer if they are closer together than our standard three feet. Thus we find that when the sights are four feet apart, as upon most modern match rifles with aperture sights, the vernier division of the scale is $\frac{1}{75}$th of an inch, this being the practically linear value of one minute of angle upon a circle of four feet radius. When, on the other hand, as in most M.B.L. rifles, the sights are but two feet apart, the linear value of one minute is but the 150th of an inch, but in each case the same equivalent upon the target is obtained, as is obvious. No sight can be considered as correctly divided if its scale is not marked upon this basis, and it has happened probably from pure inadvertence that a rifle having a back sight scaled for a four foot radius has had its sights rather *less* than that distance apart, leading some to believe that such a rifle shot with a remarkably flat trajectory since "it required so much less elevation between ranges than did other rifles."

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* "Drawing and Measuring Instruments." By J. F. Heather, M.A., No. 168. Weale's series. Lockwood and Co., London; 1871.

The happy manner in which the minute of angle fits in with our required target values has led an influential section of the rifle world, headed by Mr. Metford, to use the technicalities of "degree" and "minute," to signify their sighting work in their common conversation on angular value of elevation. So far so good; but it occurs to me that some slight misconception may arise from such nomenclature becoming current. For instance, in comparing the angles of elevation of the Metford rifle and the Government Martini-Henry, we find it stated, at page 195 of this volume, that the maximum angle of the former at 1000 yards is 2° 20′. An authorised statement is made that the angle of the latter rifle at the same range is 2° 52′ 46″. Now this latter angle is measured by a clinometer (a well-known instrument for this purpose) and from the weapon when fired in a machine rest. Mr. Metford's angle is obtained, as he tells us on pp. 224 and 226, in no such manner, but by a method which mixes up other extraneous questions with this particular matter, therefore, I think it rather a mistake to allow the divisions upon rifle sights to be spoken of as degrees and minutes, unless they are really so, and actually measure the exact angle contained between the axis of the barrel and the line of aim at the moment of firing. It is but a small matter certainly, but it is as well to avoid error if possible, especially when by calling the minute spaces "points" all possibility of clashing with the true angular values, when these latter are stated, is done away with. Several rifle makers adopt this view, and it can be no greater hardship for a man to allude to his elevation as 135 *points*, than to indulge in the misleading denomination of 2 *degrees* 15 *minutes*. The scales upon the front sight, for compensating side deviation of the bullet by the action of wind, rarely require to be as finely graduated as the smallest value obtainable upon the back sight, and therefore a vernier scale is a superfluous complication here. The front scale only needs dividing into spaces equal to not less than two minutes of angle upon the back sight; thus, with sights three feet apart, the scale upon the front sight would be divided into 50ths of an inch; indeed, some consider this as too fine and trying for the eye, and prefer 25ths, it being quite easy to adjust these to halves when it is necessary.

From the fact of the B.L. "Any" rifle having only, as it were, just sprung into existence, there are but very meagre data as to its excellence of performance or otherwise, as compared with the highly accurate shooting of its very artificial predecessor "the swabbed out one." No doubt the coming season will show that most excellent work can be done with a B.L. rifle fired continuously, as our M.B.L. has already shown; and could we only eliminate the remaining artificialities of this class of weapon, no doubt we should obtain some really useful information. I might give my readers some information on the most generally approved sizes of apertures, both for back and front sights, but such data are purely technical, and I find each rifle maker in this branch of business has his own particular views, shared more or less by his customers, and this renders it unnecessary for me to approach the subject. The question of ammunition for these rifles, and the best methods of loading, are also points to which the same remarks apply, full instructions being supplied for each kind of rifle by its maker, and rarely are there many points of coincidence in these details, though all strive to reach the same goal—the "bullseye."

# CHAPTER IV.

## THE SERVICE RIFLE AND ITS AMMUNITION.

IMMEDIATELY upon the successful conversion of the large-bore Enfield M.L. rifle to the Snider B.L., attention was at once directed to the advisability of a similar development of the small-bore M.L. rifle for the purpose of obtaining a B.L. rifle having much greater accuracy, range, and power than the Snider possesses. For some considerable time this question of a good small-bore breech-loading rifle was before the public in a very crude state, some wonderful and, indeed, fearful mechanical arrangements called breech actions being from time to time produced, and sinking to oblivion one after the other, generally after blowing off some unfortunate individual's fingers, or otherwise maiming bold but rash experimentalists. The authorities at the War Office took up this matter in their usual way, first offering a reward to gunmakers and others for the best rifle and its ammunition, complying with certain conditions laid down by them. A number of inventions were brought forward in compliance, more or less, with these conditions, and a sub-committee was appointed to adjudicate on the matter, care being taken to have no person on the committee who, from previous training or experience, possessed any knowledge whatever of the complicated mechanical, and other questions involved in the construction and detail of a rifle and its ammunition; though some concession to common sense was made by placing a celebrated rifle shot on the committee. After continuing their labours for nearly three years, during which period, as their printed reports show, they developed pretty fully their striking incapacity for the work they were selected to perform, they finally selected the breech action of F. von Martini and the barrel bearing the name of Mr. Henry, of Edinburgh, to be incorporated together by the staff of the small arms factory at Enfield, into what was to be a model long-range arm of precision. This stage in the history of the weapon did not pass without considerable cost to the nation, as some in authority turned inventors, and a considerable amount of time, and large sums of money, were thrown away in "safety locking bolts," "trigger and tumbler rests," devices quite extraneous to Martini's invention, and long since consigned to the rubbish hole. The cartridge selected for this rifle (see figure), was the "Boxer," fully described at pp. 292, 295, but, for mechanical reasons connected with the breech action, it was found necessary to crimp or bottle-shape this cartridge to the form shown in Fig. 173, thus adding other grave objections to this form of cartridge shell. A solid paper-covered cylindrical bullet, having a very slight cavity in the base, and 480 grains in weight, was used, with a wad of pure, hard beeswax, between jute disks placed over the powder (85 grains). This cartridge was at that time highly thought of by the officials connected with the Government establishments and concerned in its production; and, in a comparison between the relative value of this shell as contrasted with the solid drawn one, when it comes to the question of the respective values of the two kinds of shells for shooting, we find that in the absence of any direct experiments it is stated that, in "Col.

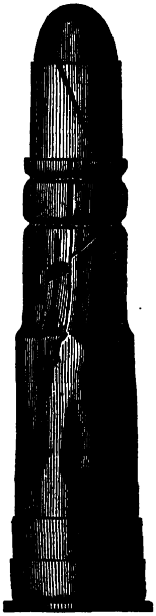

FIG. 173.
MARTINI-HENRY CARTRIDGE.

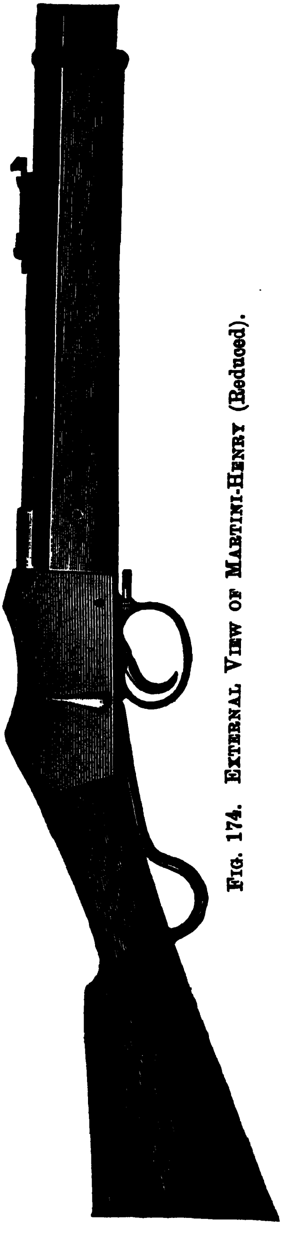

FIG. 174. EXTERNAL VIEW OF MARTINI-HENRY (Reduced).

Boxer's opinion the superior shooting of his model shell was," &c., &c., a fair specimen of the ability of the committee in the matter of obtaining evidence. At length the rifle was launched before the public, and met with a storm of disapprobation, in some respects unreasonable, and with an equally unreasonable amount of support from its partisans. However, the lapse of time has shown that, as an accurate long-range weapon it has proved to be a complete failure, though it may not have broken down so utterly in every respect as its worst enemies prophesied it would.

Having the good fortune to be brought directly into comparison in the matter of short and mid-range shooting with a feeble large-bore weapon, like the Snider, its generally marked superiority to the latter at these ranges has gone far towards condoning in the eyes of the rifle world its other numerous shortcomings. Setting aside the defects of the cartridge and barrel, the breech mechanism has turned out to be much better than was expected, and would possess few defects if the hand of man was about twice the average size, and if delicacy and uniformity of trigger-pull was not a factor of importance in a long range arm of precision; and last, but not least, if it was not an ascertained fact of the gravest importance that small bore rifle barrels *must* be cleaned or wiped out from the *breech end.*

The figure on page 486 represents the distinctive parts of the now tolerably familiar outside appearance of the Martini-Henry rifle. It shows the unfavourable situation of the trigger, and the wide stride of the hand and finger required to grip the weapon and manipulate the trigger in the act of firing. The main handle or under lever used in opening the breech is no doubt an excellent arrangement for military purposes generally, though it is alleged that in the Martini-Henry carbine, used by the cavalry, it sometimes becomes entangled with the reins. The interior mechanism of the Martini breech is not so familiar to the users of the rifle as it should be, and I propose to give a short description of it and its peculiarities, without being too strictly technical, and refer my readers to the accompanying illustration (Fig. 175) showing a vertical section of the breech-action through its centre, the tumbler and trigger not being section-lined for the sake of clearness.

The "shoe," or metal framework, containing the components of the breech, is indicated by the letters (AA) within which on a hinged joint swings the block (B), whose motion is controlled by the main handle or lever (C), this latter also supporting the block in firing position, as shown in the figure. In relation to this function of the main handle it should be noted that, turning as it does about and upon the main axle (D), any resistance in closing the breech block is transmitted to this axle, though, as will be seen, this axle is the centre of motion of the "tumbler" of the firing apparatus, and has to be moved round with this latter in each operation of firing. The block (B) contains the heavy firing pin (E) actuated by a powerful spiral spring abutting upon the hollow slotted stop-nut (F). The

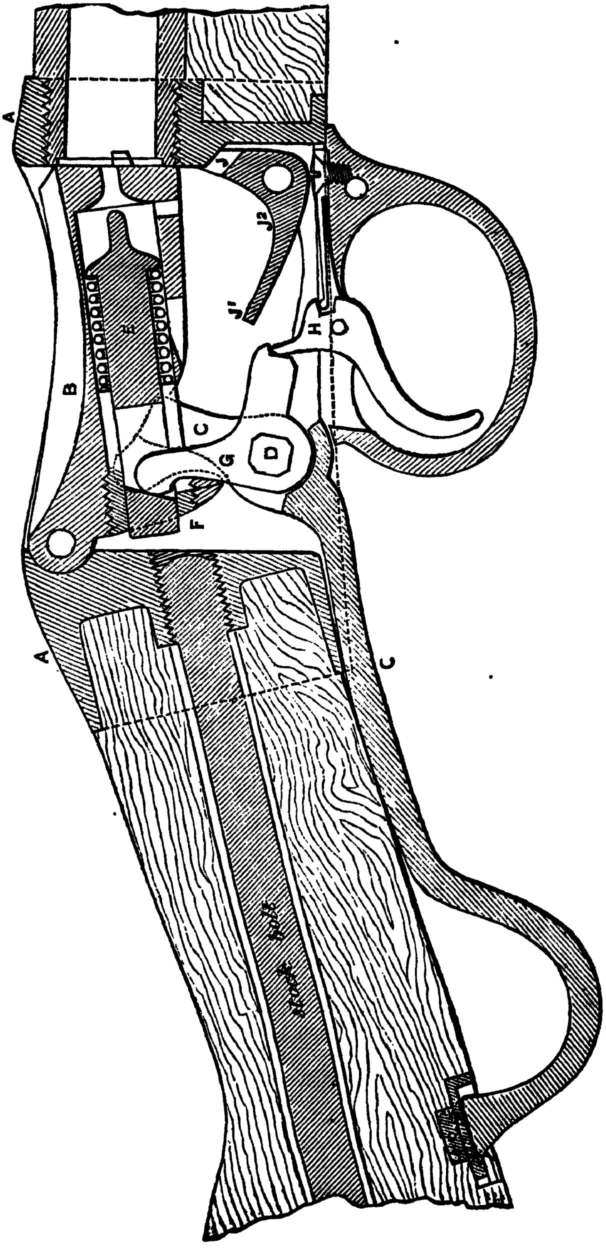

Fig. 175. Martini-Henry Action (⅓ size).

firing pin is controlled by the tumbler lever (G), whose upper end engages into a slot in the former, the tumbler fitting securely on a squared portion of the main axle (D), this latter terminating on the outside of the shoe in a finger-like projection—the indicator, shown in the external view of the rifle (Fig. 174). Thus this axis can only turn and the indicator perform its functions when the tumbler itself works, as it does in the act of full-cocking and firing. When, by a downward movement of the main handle, the block is depressed, at the same time the tumbler is carried to the position of full-cock, its lower end engaging, by means of a notch or "bent," with the trigger-scear (H), the same movement acts on the extractor—a bent lever shown by the letter (J), the lower side of the block first coming into contact with the end of the extractor lever at (J 1), and there exerting considerable force to withdraw the cartridge shell; and then, on the continuance of the downward motion further operating upon the extractor with its extreme end at (J 2), with increased velocity of movement, thus giving the "flip" necessary to the ejection of the shell from the trough formed by the upper surface of the block and the sides of the shoe. The cocking process is completed by the return of the block to the closed position, the firing pin being retained in its withdrawn position by the tumbler, supported by the trigger. When the block is moved upwards by the action of the main handle, the mainspring suffers increased compression from the stop-nut in the block; this reaches its maximum when the block is in its place with the fork of the main handle, supporting it in position, as is shown in the figure. In consequence of the very short travel of the firing pin, and the manner in which a spiral spring so applied exerts its force, it has been found necessary, to avoid misfires with the regulation primer, to use a mainspring of some forty or fifty pounds in strength, when compressed as shown in the figure.

It will be easily seen, on examining the relative length of the two arms of the tumbler lever, that this pressure is transmitted to the trigger scear, and that the points of contact of these two components (necessarily delicate and small in area for the purpose of obtaining instantaneous disengagement in the act of firing) must suffer from the effects of this great pressure, as in fact they do, and this is the chief cause of the defective and varying "pull off" of this rifle; and another cause, as I have before indicated, the fact of the main axle labouring as it does under the varying load transmitted to it by the main handle in closing the breech against differing resistances, and then having to be dragged round by the tumbler in the act of firing. From this latter cause accidents have arisen that would have been avoided if Martini's original design had been in this particular point carried out, as he made the tumbler turn *upon* and not *with* the main axle, so that any pressure upon the latter from the breech-closing arrangements could not affect the working of the lock mechanism. It will be observed that the main handle is secured in the closed position by engaging with a small spring catch let into the underside of the stock butt. The mode of attaching this latter portion of the stock to the shoe or frame of the breech action has been proved by experience to be fairly sound; but, as this detail is carried out in the Martini, the "grip," or hand of the rifle, is caused to be unduly large at a point where any excess in size over the proportions of ordinary weapons to be used by ordinarily sized hands is extremely undesirable, to say the least of it, and might easily have been avoided in the first instance.

The only other feature requiring consideration in this rifle is, that the barrel is rifled, as stated, upon the Henry principle —the model barrel adopted by the committee, and with which the shooting was made upon which they grounded their decision to adopt it as the service arm was some three-quarters of a pound heavier than the present regulation model, which only weighs about 3lb. 7oz., while the barrels of the most approved modern M.B.L. rifles are nearly 5lb. and upwards in weight. It needs but little practical acquaintance with the subject to appreciate the fact that a barrel so light is extremely unfit for use with so heavy a charge as that fired in the Martini-Henry rifle, while the cool audacity of still further reducing the weight from that of the first approved model is most refreshing.

The annexed figures show a longitudinal section of the M.H. bullet, with the cavity in the base. This bullet, weighing only 480 grains, is generally considered far too light in proportion to its calibre for accurate work at the extreme ranges; but on account of the already great recoil of this rifle, due to the defective proportions of barrel and cartridge, the use of a heavier bullet cannot be contemplated. The sighting details of the Martini-Henry are a distinct improvement upon these points in the Snider. The backsight with a wide opening in the leaf, introduced upon the Whitworth rifles, having been taken as the model, was placed upon the barrel much farther from the firer's eye than had before been the practice, resulting in a great optical advantage in aiming. The use, too, of the flat edge of the elevating slide-bar of the sight instead of the notch or V, especially when combined with the wind-gauge lines marked thereon for lateral allowance, was decidedly a step in the right direction. Herewith is a table showing the chief points in connection with the shooting qualities of the Martini-Henry rifle, that it is advisable for the rifleman to become acquainted with:

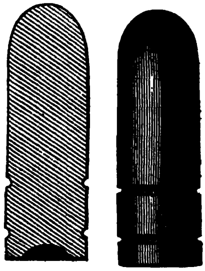

FIG. 176.
M.H. BULLET.

| Range. | Mean Deviation. | Angle of Elevation. | Height of Trajectory. | Velocity. |
|---|---|---|---|---|
| Yards. | Feet. | | Feet. | Ft. per sec. |
| 100 | 0·09 | 0° 25′ 30″ | 0·234 | 1167 |
| 200 | 0·18 | 0 34 30 | 1·064 | 1053 |
| 300 | 0·32 | 0 48 45 | 2·645 | 982 |
| 400 | 0·41 | 1 4 45 | 5 074 | 922 |
| 500 | 0·55 | 1 19 0 | 8·555 | 869 |
| 600 | 0·77 | 1 40 12 | 13·155 | 821 |
| 700 | 0·95 | 1 59 9 | 19·012 | 778 |
| 800 | 1·20 | 2 17 12 | 26·360 | 738 |
| 900 | 1·50 | 2 38 2 | 35·307 | 700 |
| 1000 | 1·85 | 3 5 42 | 45·848 | 664 |

Taking it altogether this table may be considered fairly correct as a record of the performance of an individual rifle, it bears internal evidence that it can scarcely be the mean result of a number of weapons tested for the points illustrated, one noticeable feature being that the angle for 1000 yards is given as 3° 5′ 42″, as against 2° 52′ 46″, the angle given in another table of the results of experiments made some years ago. We may, therefore, while fully admitting that individual rifles vary several minutes of angle in elevation from structural causes, and that these experiments are also liable to be affected by the varying atmospheric conditions under which they are performed, venture to accept the angles given in this table as the more recent ones obtained, though it will be noticed that when we investigate the increase of angle between ranges, we shall find a rather peculiar trajectory curve; for instance, we find an increase between 500 and 600 yards of 21′ 12″, while between 600 and 700 yards it is only 18′ 57″, and again between 700 and 800 yards only 18′ 3″. There is evidently some slight error here, though between 800 and 900 and 1000 yards, the values given nearly approach those obtained in actual shooting.

It will be interesting to place upon record here what may be considered as the finest results hitherto obtained with the Martini-Henry rifle, firing the Government ammunition, in public competition, and therefore, being thoroughly *bonâ fidè*.

At the late Middlesex Rifle Meeting held at Wormwood Scrubs, Private G. Rosenthal, H.A.C., made the following score, which is probably the best actually made under similar circumstances up to date.

| | | |
|---|---|---|
| 200 yards | 4 5 4 5 5 5 5 = | 33 |
| 500 „ | 5 5 5 5 5 5 5 = | 35 |
| 600 „ | 5 4 5 5 4 5 5 = | 33 |
| | | 101 |

The highest possible score being 105 marks. The shoot was made in the prone position, and with a rifle of private manufacture;* this being, of course, in compliance with the Government viewers' gauges, &c.

At a M.H. competition of the North London Rifle Club this season the same gentleman made the following fine score under the new conditions of the Queen's Prize:

| | | |
|---|---|---|
| 800 yards | 3 3 5 5 3 5 5 4 5 4 = | 42 |
| 900 „ | 4 5 5 4 5 5 5 3 4 5 = | 45 |
| | | 87 |

The H.P.S. being 100 marks. This is probably the best score yet made under similar conditions.

### THE NEW MARTINI-ENFIELD.

The shortcomings of the service rifle having at length become recognised by the official mind, the result has been that for some time efforts have been made to produce a superior weapon for the future arm of the British soldier. In 1880 a match was shot between teams of the Midland Rifle Club and the North London Rifle Club at the long ranges, and the scores obtained were so excellent as to cause some considerable amount of notice to be given to the subject, and surprise was expressed that the service rifle was not represented in the shoot. For some time, however, this rifle had been conspicuous by its absence from the long-range prize lists at the Wimbledon Meetings. The authorities, stimulated by this occurrence, decided to appoint a sub-committee to investigate the question of an improved small-arm for the service rifle, and the researches of this committee, together with the efforts of the officials of the Enfield factory combined, have produced the new model weapon that I will endeavour to describe; though, as the final stage of experiment in some respects has not yet been passed by this arm, and it is in consequence not yet formally adopted into the service, my information is not so complete as I should wish it to be; and changes in detail may yet be made, perhaps in some respects rendering my description imperfect. Externally the new rifle resembles the present one, as the same breech-action is used, the authorities not yet having realised, apparently, that among other points it is most necesssary that B.L. rifles should admit of cleaning from the breech end. Some concession, has, however, been made in another direction, by an effort to reduce the size of the "hand" by modifying the shape of the action at this point, but only to a slight extent. A most noticeable feature in the new gun is the novel form of the fore-stock, in which usually the barrel is embedded; whereas in the new pattern the barrel is not fitted into a groove in the wood, but simply lies upon the flat upper surface of the fore stock, to which it is attached in the usual manner by bands. This shape is adopted mainly in order that the barrel may be got at upon the whole of its external surface, so as to be wiped and oiled if necessary—much objectionable corrosion having taken place when the barrel is partly covered by the wood, as heretofore has been the invariable practice.

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* By P. Webley and Son, Birmingham.

A detachable wooden cap or cover is fitted to the barrel where grasped by the left hand of the firer, to prevent inconvenience from the barrel heating with rapid firing—a contrivance introduced some twenty years ago by Westley Richards. The sighting arrangements of the new arm are of a two-fold character, the fore-sight and back-sight are fixed upon the barrel in the usual manner and position, the back-sight being very similar to the present model, only that a laterally movable slide, that can be pushed from side to side with the thumb and fingers, and so adjusted in reference to a scale for wind allowance, is in this case combined with the usual vertically moving slide for elevation adjustment. This slide, when the sight leaf is folded down, is used for the shorter ranges, up to 500 yards, a short auxiliary flap to suit this latter range is also fitted to the sight, so that it can be at once raised, and without further adjustment it will enable the arm to be effectively used through the entire "dangerous space" covered by the weapon, when fired at that amount of elevation. The rifle as at present constructed has an additional set of sights, that can be attached when firing at extremely long ranges is considered necessary. The sights are fixed, when in use, at the left side of the weapon, the back-sight being merely a bar hinged so as to fold close to the barrel when not in use, and capable of being opened out so as to afford a fixed aiming base. The front-sight, having both vertical and lateral adjustments, is fitted into a slot in the left side of the upper band, and, when opened out ready for use, is of an L shape, the vertical and longer arm sliding in the band slot, and graduated so as to permit of vertical adjustment for the required elevation, while the shorter horizontal arm has a sight of the usual shape, that can be moved at will, to give the desired amount of wind compensation. The greater portion of the sight depends below the rifle, and the firer does not have to raise his head abnormally when aiming at an object, say 2000 yards off, but the lowering of the front sight elevates the muzzle of the rifle, and thus produces the desired effect. Of course it remains to be seen if such sights are desirable or necessary, or capable of being used in actual warfare. The next points to be considered are those relating to the barrel and the cartridge. The barrel, which is some ten ounces heavier than that of the Martini-Henry, is of a much smaller calibre, only ·400 in diameter, or the 20th of an inch less than our present small-bore, the object in introducing this feature being, of course, to lower the trajectory, and make the chances of error in judging the enemy's distance so much the less.

This has been attained to some marked extent, but not without some little sacrifice in return, as it is found that the bullet fired from this small calibre is rather more susceptible to the influence of a side wind than the more massive projectiles fired from our ordinary M.B.L. rifles; again, it may be questioned whether this small calibre—which is so much the more difficult to clean and keep in order, especially in a rifle with a Martini breech, where all the chafing must take place at the muzzle—the most vital part of the barrel in relation to accuracy of fire—will not rapidly get out of order. The Henry plan of rifling has not been applied to this new arm, but a variety of the "ratchet" instead, which the authorities at Enfield have cut in rather a quaint fashion; that is, they have reversed the shape of the cut, making the long slope of the ratchet the driving side, instead of the shorter one, as is usual. As I have before remarked, there is but little advantage either way in small variations in form in plans of rifling, and this may be of use under the conditions existing in this particular arm and its ammunition. For instance, it is proposed to use an unpatched bullet, and, consequently, the paper shearing value of the usual form of ratchet groove is not wanted; and as there is no material change in the plan or substance of the lubrication employed in the cartridge, it is important to offer sloping surfaces to the gas blast (see p. 347).

As to other and more recondite questions they have probably never yet entered into the minds of the designers of this arm.

The cartridge is a solid bottle-shaped one, with about the same proportions of powder and a little lighter bullet than those of the M.H. cartridge; and no doubt, under some conditions, some very fine shooting has been obtained from this combination; but I can say nothing either one way nor the other, except that we must wait to see it in the hands of our great and unequalled volunteer shots before we can fairly arrive at a proper estimate of the merits and defects of this new plan.

The simple fact that professional advice has been, as usual, strictly avoided during the construction of this arm, would cause anyone versed in the rifle experiences of the last twenty years, to look rather dubiously on a weapon produced by merely military men and amateurs, though aided by the Enfield staff. But, unfortunately, this body, from their isolated position and necessarily restricted base of operations, making as they do but one type of rifle to their own standard of excellence, cannot possibly have the wide range of experience only to be obtained in the general rifle business, and which should have been utilised by any committee dealing with so important a question as the future national weapon.

# CHAPTER V.

## THE MODERN MILITARY BREECH-LOADING RIFLE, OR M.B.L.

It will not be necessary in approaching this division of my subject to consider any other specimens of this class of weapons other than those of approved and currently existing types. I can, therefore, only allude to such early forms of the M.B.L. rifle as the "Henry," having the drawback of a side lock requiring to be cocked in the same manner as a muzzle-loader; the "Westley Richards falling block," an early type of self-cocking single rifle breech action, whose clumsiness of design and ponderous weight soon consigned it to oblivion; the "Soper," a more meritorious arrangement, full (indeed, too full) of ingenious mechanism, but which has latterly passed away from before the public; and other more or less ingenious constructions that it is not now necessary even to name. I shall proceed to give descriptions and illustrations of the four or five rifles that can now be considered as fairly before the public, taking them in the order of their appearance upon Wimbledon Common.

### THE FARQUHARSON-METFORD, BY GIBBS.

The first rifle we have to notice is the Farquharson-Metford rifle, made by Gibbs, of Bristol. Whatever may be the ultimate degree of success attained by rifles constructed on Mr. Metford's principles, a large share of the credit attached to such success must always belong to Mr. Gibbs, to whose energy and perseverance it is due that the niceties of detail and general accuracy of manufacture these rifles specially require has been applied to them, and in a manner to insure the success of the plan, and establish it beyond doubt before it was in any way taken up by other rifle makers.

It is not necessary for me again to go into the special features of the Metford plan of rifling and bullet; suffice it to say that when carefully made, and in good condition in every particular of rifle and cartridge, the Farquharson-Metford weapon has given most excellent results. The breech action is given in section in the accompanying engraving (Fig. 177), in which most of the parts are shown in two positions—*i.e.*, with the breech either open or closed.

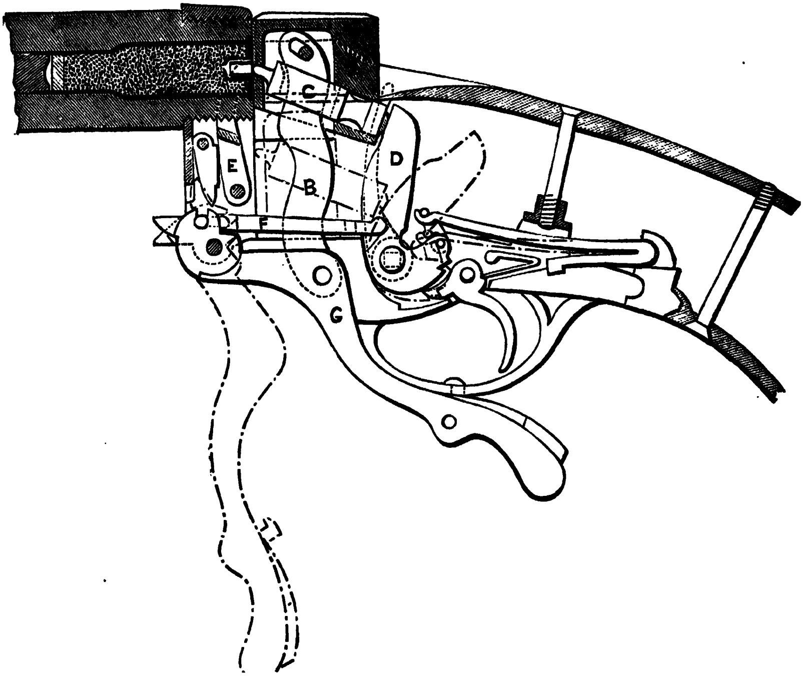
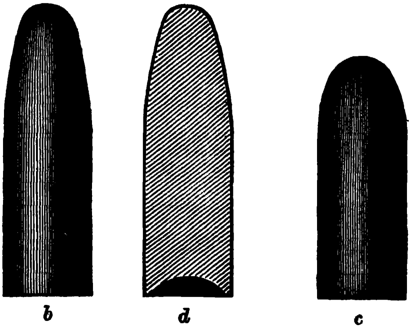


Fig. 177. Sectional View of the Farquharson Breech Action, by Gibbs.

The breech-action is in principle the invention of Mr. Farquharson, of Blairgowrie, the originator of the shooting position bearing his name, and was purchased of him by Mr. Gibbs as a registered design. In construction it is founded on the well-known block (A) lever (G) and link (B), first introduced in England as "Sharps'"; but Mr. Farquharson added a simple and effective mode of self-cocking, consisting of a horizontal bar and cocking rod (F) swivelled to the fore end of the hand lever (G) and beyond its fulcrum. This bar engages in a recess, or notch, on the breast of the hammer (D) above the pin, or axle, on which it works; when the hand lever is depressed to open the breech, the hammer is by this horizontal bar pushed back into the firing position, shown throughout in dotted lines; the breech block then falls to the bottom, when it comes into contact with the ejector (E), and the empty case is thrown out. Another important part of this action is, that provision is made for releasing the striker from the back of the cartridge after firing by means of a slot in the link (B), which allows the block to remain unmoved for a moment, when the hand lever is depressed to open the weapon, so that the hammer is pushed back about the eighth of an inch before the block moves. The ejector of this action is of greatly improved construction, and is introduced in a subsequent patent. (See Fig. 178.) It possesses greater power of ejection than any other to be found; and the lock is of simple construction, having only one spring in its internal mechanism, viz., the mainspring. Nor are there more than two screws in the entire action, pins being used, which can be pushed out and put in by the most unskilful hands; and the whole internal work—that is, lock, lever, link, and breech block—can be lifted out bodily, without derangement of any kind, and oiled, and cleaned, and replaced without a single tool, or the aid of an armourer.

It was first issued to the public in the form of a military

breech-loader, with the Metford barrel, in the year 1874, and it carried the Duke of Cambridge's Prize in five successive years. This prize is competed for at 1000 yards, fifteen shots, without cleaning out, which is considered a severe trial of the non-fouling of any rifling, in addition to its accuracy. It is also well adapted for a sporting rifle, and is extensively patronised, as already stated. (See Fig. 179.)



Metford Bullets.

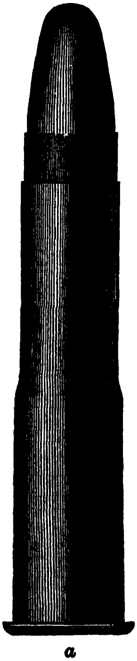


Fig. 180. Metford Cartridge.

The annexed figure (180) shows an external view of the loaded cartridge used with this rifle, also a view of the bullets, both heavy (*b*) and light (*c*), with a section of the former (*d*) showing the cavity in the base.

For some time Mr. Metford held out for the lighter bullet, 480 grains in weight, as the thing to be used with his moderate powder charge in a B.L. rifle; but his views underwent a change about 1879 or 1880, since which time the heavier 540 grain bullets of a rather peculiar shape have been almost universally used with his rifles.

Mr. Metford professes to use no lubrication in his cartridges, and, indeed, so small a powder charge does not demand much, all things being in perfect condition; but it is well known that the tightly fitting felt wads used as a fire block are well saturated with beeswax; and as this substance is the recognised means of lubrication adopted in the Government small arm ammunition, we must believe that some little help is afforded in this respect by this material, though it is generally looked upon as a rather refractory agent for the purpose. If Mr. Metford issued for a season waddings totally free from admixture with any lubricating agent, he would then have no difficulty in persuading the public that his admirable rifle worked without such aid. The sights (Figs. 181, 182) are too well known to need description.

### THE DEELEY-EDGE-METFORD RIFLE.

A rifle bearing this designation first appeared at Wimbledon in 1878, but the breech action was very different from that of the present rifle I am about to describe; in fact, the then pattern action was found so very unsatisfactory that the new model was brought out most opportunely a year or two ago. (See Figs. 183 A, B.) Attached to the Metford barrel, identical in every principal feature with the barrel used by Mr. Gibbs, this rifle, of course, would be naturally expected to shoot with a similar amount of accuracy, which in fact it does, though as a rule I believe a rather increased powder charge is used with it, as compared with that originally advocated for use in a B.L. rifle by Mr. Metford. Fig. 184 gives an idea of the side external view of this breech action. Fig. 184A shows a view of the opposite side of one of these rifles, with the stock butt removed, and shows how a safety bolt is applied,

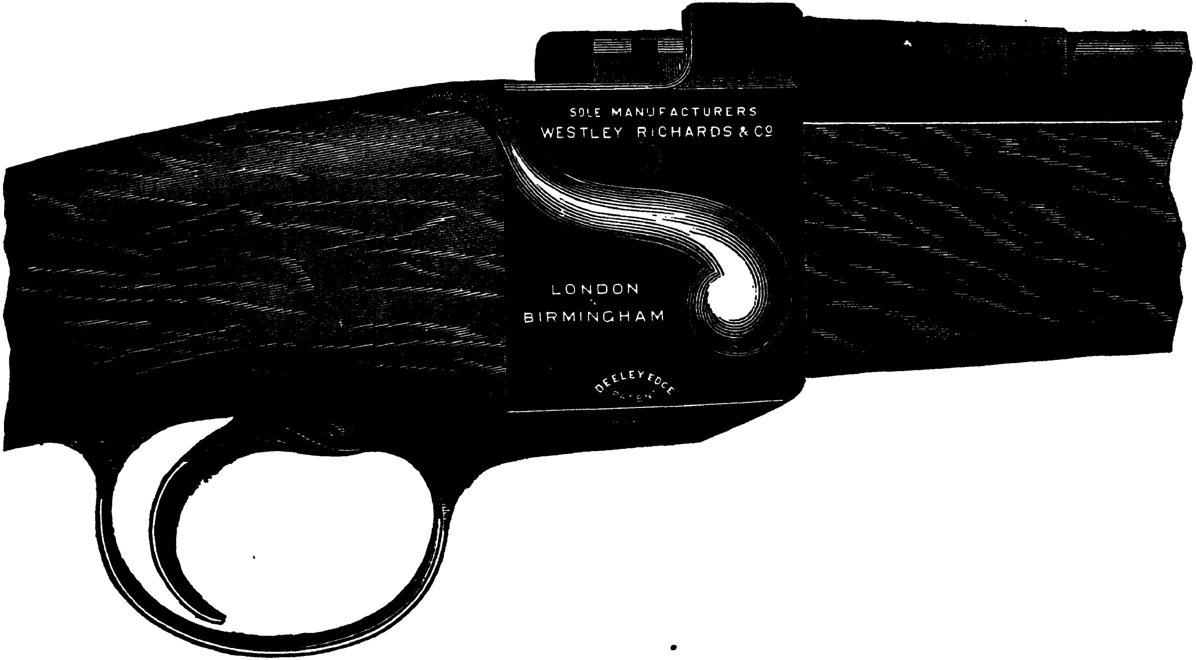


FIG. 184. EXTERNAL VIEW OF DEELEY-EDGE-METFORD RIFLE, SHOWING BREECH ACTION.

though, as my readers will perceive, its action is rather too near the centre of motion of the hammer to be quite a perfect mechanical arrangement.

In this action, which is upon the sliding-block principle, the breech has a vertical groove, or slot, at right angles to the bore in which the block works; this block is depressed and raised by means of a side lever, which actuates an axis crossing the body of the gun under the breech end. This axis is the main feature in the mechanism, and performs the threefold function of opening the gun, cocking the hammer, and working the extractor. The axis has on one side a projection which takes into the recess on the bottom of the block, and when the lever is depressed the block also is depressed and the breech opened. On its left side it carries a projection for working the extractor, and in the centre of it there is a short arm, or projection, which effects the cocking in the following manner:—At the rear of the axis is a small lever, one end of which is situated under the short arm of the axis, its other end engages under the shoulder on the breast of the hammer. When the hand-lever is depressed the fore-end of the lever is depressed by the short arm on the axis, and

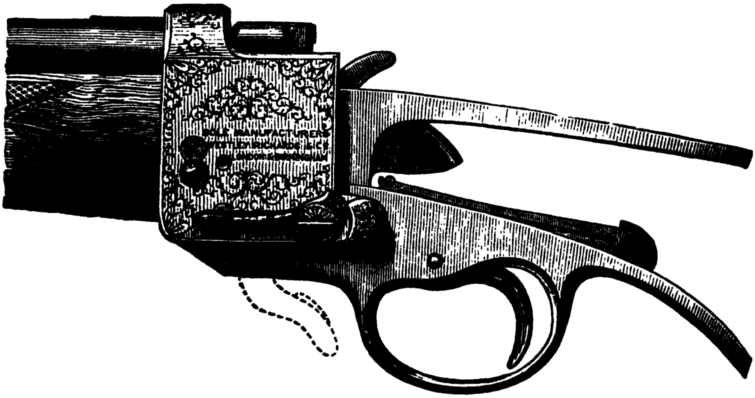


FIG. 184A. DEELEY-EDGE BREECH ACTION, SHOWING SAFETY BOLT.

thereby the rear end is raised and lifts the hammer into cock,* in which position it is retained by the ordinary bent and scear.

The main-spring and scear-spring are of the usual gun-lock type.

The action is light and simple in construction, and of great durability.

The military model of this rifle is constructed in accordance with the N.R.A. regulations, Class IB, for military breech-loaders. The action is light, which enables a heavy barrel to be used, and by depressing the lever, a clear view of the barrel can be obtained. This renders it easy to inspect the rifling, and to clean the barrel from the breech end, which is of great importance. (See Fig. 183A.)

The cartridge used is the well-known Westley-Richards No. 2 musket cartridge, with 80 grains powder, two waxed waddings, and a specially prepared projectile, weighing 540 grains. If required, a lighter bullet, weighing 480 grains, is supplied for short ranges. The broad back sight is upon an improved principle, with a sliding wind-gauge bar and graduated scale, as now permitted by the N.R.A. The top-piece and bar have each a central platinum line, and are supplied with a straight-edge or V notch to order.

The rifling is upon the celebrated Metford system, the form employed in this rifle being what is termed a shallow seven-groove segmental cut. As regards the accuracy of this weapon (and also the Match Rifles made by the same firm), references need only be made to its public records, the official reports of the National and other Rifle Associations showing that it is at least fully equal to anything before the public.

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* This feature is not wholly novel, it having been applied in Manton's patent some years ago.

## THE DEELEY-EDGE-METFORD MATCH RIFLE.

The same breech action being employed as for the military rifle, similar advantages as to weight of barrel, cleaning out, &c., are obtained, but the construction of the match rifle is, of course, in accordance with the N.R.A. regulations for "Any Rifles." It is half-stocked, with a pistol grip, and weighs 10lb. (See Fig. 183 B.) In this match model an addition is made to the breech action, in the shape of a neat tumbler bolt placed upon the left side of the breech, which securely bolts the hammer when at cock. The stock can be constructed for any of the positions now adopted by small-bore men. This barrel is also rifled upon the Metford system, the form of rifling and other points having been recently modified to meet the new rule of the N.R.A. which prohibits cleaning. The sights (Figs. 185–6), which have been constructed in accordance with the views of some of the most eminent shots of the day, consist of a long orthoptic back sight, which can be used upon the grip or heel, as desired, and a wind-gauge fore sight, with spirit level, shade, &c., for which fore sight discs of various patterns are supplied to interchange. There is an ingenious arrangement in the back sight by means of which the zero may be adjusted, and the angle of elevation made to read differently. This enables men who are shooting at nearly the same angle to alter their zero (which can be done instantly) and shoot at one common angle—a considerable advantage in team shooting. There is also a similar arrangement in the fore sight by which the wind-scale can be readily re-adjusted. This match rifle employs the same cartridge case and projectile as the military model, but the charge of powder is increased to 90 grains.

## THE DEELEY-EDGE-METFORD MILITARY AND MATCH BREECH-LOADER COMBINED.

In order to meet those shots who desire to take up match rifle shooting as well as military work, without incurring the

expense of two rifles, Messrs. Westley-Richards and Co. are issuing a combination weapon; that is to say, they fit up the military rifle with best orthoptic match sights. The match fore sight is constructed with a collar, which slips on to the muzzle in rear of the ordinary fore sight, and is secured by a screw. A bed for the orthoptic back sight is let into the stock, and when these match sights are put on the rifle is ready for "Any Rifle" competitions. They can be removed instantly, and the weapon again becomes a regulation military breech-loader.

Messrs. Westley-Richards and Co. have secured the exclusive control of the breech action, so they are the sole manufacturers of the Deeley-Edge-Metford rifles.

The ammunition used with this rifle is the same as that used with the rifle just described.

### THE WEBLEY-WYLEY M.B.L. RIFLE.

Another of this class of rifles specially constructed for a high degree of accuracy of fire at the long ranges, is the above named weapon, manufactured by the firm of P. Webley and Son, Birmingham. In this rifle (Fig. 187A) is carried out to its fullest extent that well known and favourite principle among rifle shots—viz., the use of a heavy barrel. This can be done in this particular instance, in consequence of the exceeding lightness of the breech action, which is quite a pound lighter than the Government pattern Martini breech. This thrown into the barrel enables the maker to obtain one of 5lb. and upwards in weight as compared to the M.H. barrel of only 3½lb., the complete rifle still not weighing more than 9½lb. In this matter this rifle, which first appeared in 1879, has most decidedly led the fashion since become general among M.B.L. rifle makers, who, before their attention was thus called to this important detail, had somewhat lost sight of its importance, influenced no doubt by the scanty proportions of the barrel the Government had thought fit to adopt. This breech action, though so light (not quite 1¾lb. in weight), is strong and compact; the act of opening the breech both puts the lock mechanism to full cock and extracts and ejects the fired shell. The mode of igniting the cartridge is by the sharp blow of a hammer urged by a light mainspring, but having a considerable "scope" or amount of blow. This hammer is situated in the centre of the upper strap of the action "body," and can be operated from the outside by the thumb, and so placed at full or half cock. The accompanying figure (188) will give an idea of the appearance of the breech of this rifle, showing as it does the mode in which the block works in the shoe or body of the action; also the situation of the hammer and trigger:

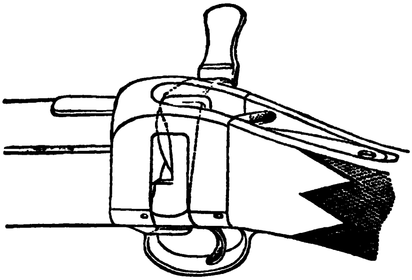

FIG. 188. WEBLEY-WYLEY BREECH ACTION.

In consequence partly of the large angle through which the hammer moves, and the position of the firing pin or striker, which coincides with the axis of the barrel, a very light and elastic mainspring of the simple flat form is amply sufficient to insure ignition, and, as a necessary result, the "pull off" of this rifle is most remarkably "sweet" and uniform.

The breech action is operated on in a somewhat similar manner to that of the Snider rifle, though the extraction is effected without an extra motion being required, as in that arm. The handle or main lever is simply an extension upwards from the right-hand side of the breech block, as is shown in Fig. 188. Although this arrangement has a very neat appearance, if an objection were raised against it, it would be on the grounds that, first, there may be a want of that surplus leverage required at times for the extraction of a defective and refractory shell; secondly, that the action might be more affected by the sand test than some others, in most other respects this breech action reflects great credit upon the mechanical ingenuity of its inventor, Mr. A. Wyley, who has in its construction displayed great ability in considering every important detail of the necessary mechanism, and in compressing these into such a compact form—a point much neglected by most designers of breech actions for military rifles before he, by his work, called attention to the importance of keeping the breech within reasonable limits of both weight and size, so that the surplus metal can be thrown into the barrel, where it is of considerable value.

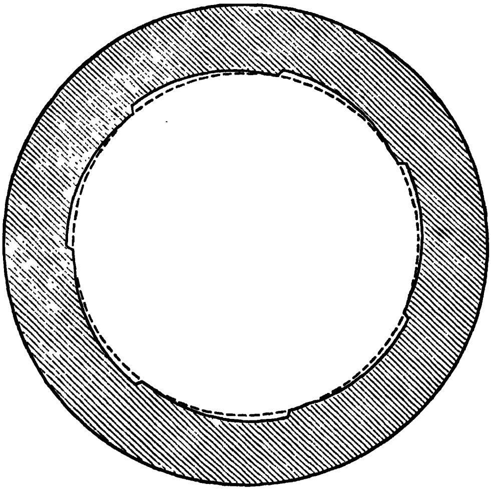

FIG. 189. ENLARGED VIEW OF "RATCHET" RIFLING, AS SEEN FROM BREECH END OF BARREL, USED IN THE WEBLEY-WYLEY M.B.L.

The barrel of this rifle is about ·458 in calibre, and is rifled as is shown in Fig. 189, that is with seven cuts of "ratchet" shape and with a uniform twist of one turn in twenty inches—Whitworth's standard pitch. The cartridge, which is shown in Fig. 190, is, of course, of solid metal, and is loaded with from 80 to 85 grains of powder (according to the fancy of the firer, good work having been done with both charges), and a 540-grain bullet of the shape shown in Fig. 191. In addition to the hard felt wadding used in this and other M.B.L. rifles, a lubricating wad is considered to be valuable in this ammunition. It is but a few grains in weight, and when the cartridge is properly loaded is securely placed between the bullet and powder in such a manner that there is little or no possibility of the lubricating material acting detrimentally upon either, when the ammunition is stored for any length of time. That this combination of barrel and ammunition is sound and effective, and capable of producing the finest shooting, is proved by the performances of this rifle as shown in the N.R.A. reports of the Wimbledon meetings. Introduced in 1879, and only used by comparatively a very small number of rifle shots, it has still fairly rivalled the Metford B.L.'s in carrying off most of the chief long

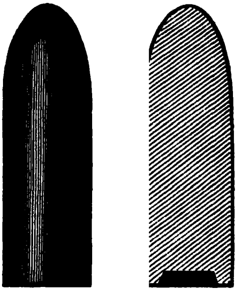

Fig. 191.
Webley Bullet.

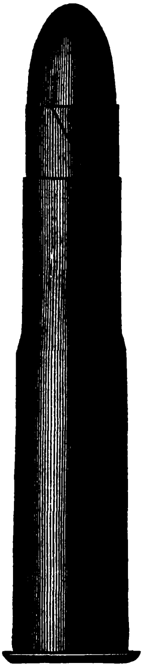

Fig. 190.
Webley Cartridge.

range prizes open to this class of weapon, though, from the early popularity of the Metford rifles, some twenty of the latter are in use to one Webley-Wyley. Among other features introduced with this rifle is the extra wide back sight shown in the annexed Fig. 192, now so generally adopted on rifles of this kind, though the wind-gauge slide bar shown in the figure is a more recent addition to it.

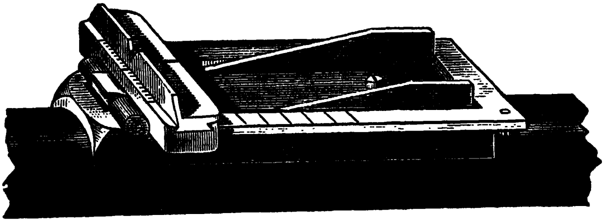

FIG. 192. WEBLEY-WYLEY M.B.L. BACK SIGHT.

An organization called the Midland Rifle Club exists at Birmingham, that was established some nine years ago for the object of cultivating and developing the M.B.L. rifle, especially at the longer ranges; and the Webley-Wyley rifle was first constructed to meet the requirements of some of the members of this club.

Since its introduction into their competitions it has carried away the great majority of their principal prizes, though their shooting is of the most exacting character, eliminating as far as possible the element of chance. I give the shot for shot record of the fine score of 99 made at one of their competitions by Corporal Bates, of the 1st W.R.V.B., using this weapon.

| | | |
|---|---|---|
| 800 yards | 5 4 5 5 5 5 5 | = 34 |
| 900 „ | 5 5 5 5 5 5 5 | = 35 |
| 1000 „ | 3 5 3 5 5 5 4 | = 30 |
| | | 99 |

The highest possible score being 105 marks.

## THE FRASER BREECH-LOADING LONG-RANGE RIFLE.

The breech-action is constructed on the vertical sliding-block principle, first applied practically to small arms by the Sharps Company of America. Rifles manufactured by this firm were used in the American Civil War, although the weight and general clumsiness of the action, with its cumbrous outside hammer, rendered it a most ungainly weapon. The system was, nevertheless, sound, and many of our best known rifle makers have worked on the same lines with a variety of modifications, but all striving to produce as compact an action as possible, consistent with strength of breech mechanism and lock work.

Working on the basis above indicated, Messrs. Fraser have succeeded in perfecting a breech in which the various limbs are much stronger than those of the Government regulation Snider or Martini rifles, and as regards strength of action shoe, I may state that, all their rifles are provisionally proved with the actions fitted to the barrels, thus undergoing the severe strain of double proof at one time.

In ordinary cases the stock is held to the action by means of metal projections, called straps, passing from the breech-shoe over and under the grip or small, with screwed pieces binding the parts together. This action is attached to the stock by a strong steel bolt entering from the butt, which serves the double purpose of securing the wood and metal by end-on pressure, and gives great rigidity at the grip, where strength is most required. (See Fig. 193.)

A detailed explanation of the working of the action seems to be unnecessary, as the illustration shows very distinctly how the several movements are effected. It may be sufficient to say that when the breech-block is lowered by means of the side lever so far as to place the rifle on full-cock, the extractor comes into operation, and is projected with great power a short distance, sufficient to ease the shell out of the chamber, the head of the hammer then forces back the safety bolt, causing a flip which ejects the empty shell clear of the rifle without the necessity for any special springs.

The action of the safety bolt is so clearly shown in the cut as to require no explanation.

The general adoption of the back position by long-range shots necessitates the use of a longer orthoptic or rear sight, and the inconvenience, not to say danger, of having this delicate sight exposed, suggested to them the possibility of forming a sight-case in the stock itself, a reference to the illustration (p. 479) will show how this has been accomplished. The recess is provided with a cover removable at pleasure, and which effectually protects the sight from injury. The improved front wind-gauge is constructed with a much larger field than usual, which enables the spirit level to be placed within the disc shield, where it lies close up to the disc and point of aim, an arrangement which reduces the strain on the eye when sighting. They further claim novelty for a reversible metal sun-shade, screwing on to front or rear as required; also for having a scale cut on both sides of sight-bed, so that the firer when in position need not turn the muzzle towards him when adjusting the sight for a change of wind. (See Fig. 194.)

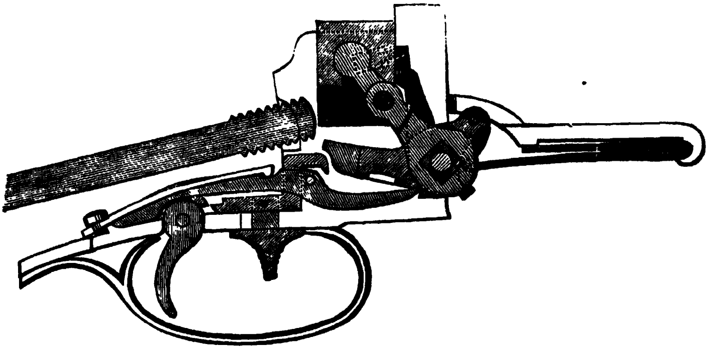

FIG. 193. SECTION OF FRASER'S BREECH ACTION.

Messrs. Fraser describe the form of rifling adopted by them in the above rifles as a "hollow ratchet," that is, instead of retaining the old saw-tooth groove, which consists of a straight plane ending in an acute angle at the minor axis of the bore, they hollow the groove and leave a land of ·05 in width. This plan has for its object the steadying of the bullet in its passage through the barrel, and also prevents that premature stripping of the patches so fatal to accurate shooting at extreme ranges, while the shape of the groove has the effect of lessening friction, and, as a consequence, giving increased velocity.

The spiral of the rifling is progressive, beginning at the breech end almost straight, and increasing at the muzzle to one turn in 16in. The bore of the rifle is ·455, and the depth of groove at resisting edge ·005. Number of grooves, 7.

The pitch of the spiral or twist has been determined by careful experiment, and they claim for this plan an almost entire absence of fouling, at the same time preventing the jamming action almost inseparable from those forms of rifling which consist of a number of acute angles.

They make use of a bottle-shaped solid drawn shell, charged with 80 grains powder, special lubrication, and a bullet which weighs 530 grains.

I here give a sketch of the Fraser bullet (Fig. 195), and also a section showing the cavity in the base. I am unable to show the entire cartridge, or to give any record of scores made by this rifle which, practically, only made its appearance during the late season, though several fine scores were made with it at the Wimbledon meeting.

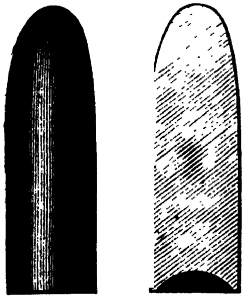

FIG. 195. SECTION AND VIEW OF FRASER BULLET.

## THE RIGBY-BANKS M.B.L. RIFLE.

This is a new breech action for single rifles, military, match, or sporting. It is a vertically sliding block action with automatic hammerless lock, and possesses the following distinctive features:

It is usual to attach the stock to the breech frame of military and other rifles by means of a bolt passed up through the butt and screwed into the frame. In the Rigby-Banks rifle this has been improved by substituting for the bolt a steel tube screwed firmly into the frame, and having on its rear end a screwed nut, which serves to hold the stock in its place. Inside the tube is a coiled mainspring 5in. in length, within which slides a steel rod whose forward end is in a convenient position to deliver, under the impulse of the spring, an effective blow upon

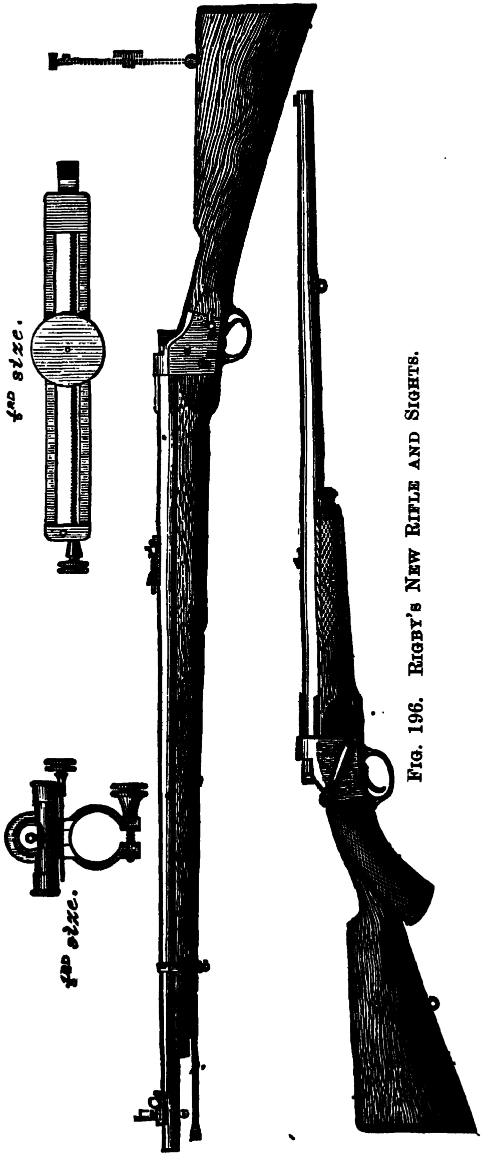
⅓rd size.
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FIG. 196. RIGBY'S NEW RIFLE AND SIGHTS.

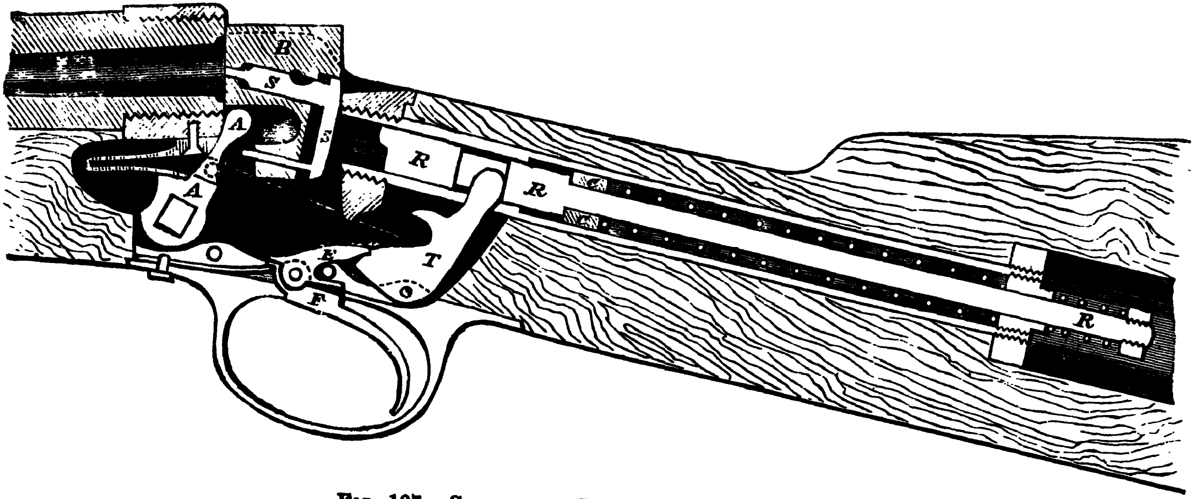

FIG. 197. SECTION OF RIGBY'S BREECH ACTION.

A A, the arm which lowers and raises the block B B.

B, the sliding breech-block, into which is fitted the striker, S S.

R R, the rod or hammer, a slot in which receives the head of the tumbler, T.

C C, the collar sliding *in* the tube and *on* the rod, R R, which is thereby made free to strike and rebound.

E, the scear shown in the bent holding the tumbler at full cock.

F, the trigger, working on the same pivot as E.

the striker. By means of a loose collar on this rod, and an ingenious arrangement which will be understood by reference to the section shown in Fig. 197, the rod is caused, after striking, to rebound into the tube, and so leave the sliding breech-block free to move up and down. This arrangement has the advantage that it places the hammer and mainspring in a closed tube, apart from the cartridge, and out of the way of wet, smoke, or dust. The rebound action removes the danger of accidental discharge in loading, to prevent which intercepting bolts are needed in most automatic guns.

The external lever is placed on the right side of the frame, and is thrown downward by the thumb of the right hand, when it is desired to open the breech, and raised again by the forefinger. A spring bears on the axis of this lever in such a way that when a part of the upward or downward movement is effected by the hand, the pressure of the spring completes it. The position of this lever presents the advantage that the rifle can be reloaded in any position of the rifleman—erect, prone, or supine—without removing the butt from the shoulder or much change of the position of the hands, and that the lever is not liable to be impeded by grass or twigs, as is the case when it is placed underneath the gun. The automatic cocking of the lock is effected by the same downward movement of the side lever. The arm on the axle, which lowers the breech, carries also, pivotted to it, a bar by which movement is given to the tumbler, and the lock brought to full cock.

An important improvement is in the striker, which plays freely in the breech-block without a spring. It is provided with a second parallel pin sliding in a hole in the block, and so placed that, should the striker from any cause fail to come back into the block after the discharge, the arm which lowers the latter comes first against the end of this pin, and compels the striker to retire into its place before it commences to lower the block.

This invention remedies the defect to which all sliding block rifles, that depend upon a spring to retire the striker, are liable, namely, that when the striker becomes stiff or sticks in the cap, and the spring is unable to withdraw it, the breech cannot be lowered, and the rifle is useless.

The lock of this rifle, which is very simple, is fitted with a novel arrangement of the scear and trigger, which is the subject of a separate patent, and applicable to all gunlocks. Its object is to secure a safe full cock combined with a trigger pull which will be easy to the finger. The trigger when pressed moves a short distance, and lifts the spring which holds the scear pressed into the bent or notch in the tumbler; it then touches the scear, the contact being easily felt, and when the aim is perfected a slight additional pressure discharges the arm. On the other hand, when quickly pressed, no appreciable delay is experienced, but the chance of jerking the rifle is much diminished.

The extractor has an accelerated motion, which throws the fired cartridge shell clear of the gun when reloading rapidly. The block and trigger plate are easily detached from the action for the purpose of cleaning, oiling, &c.

The description of the action here given refers to the lettered figure (197).

# CHAPTER VI.

## MANAGEMENT OF THE TARGET RIFLE.

The following remarks must not be taken as in any way fully covering the important precautionary measures upon which the successful use of the target rifle in match shooting so largely depends. That the soldier in actual warfare may not be able to put in practice some of the minutiæ, presently to be described, is no reason why in competitive shooting these points should not receive due attention, assisting as they do in bringing out to the fullest extent, the powers of both the rifle and the man. I regret that the limits of space prevent my treating as fully as I should wish, the very interesting questions that are in this chapter only cursorily touched upon.

To proceed at once with our subject: the first point to be considered is that of

Position in Firing.—The regulations issued by the Council of the N.R.A. prescribe several different positions of the body in firing at various distances, as is well known; and it is of the greatest importance that the shooter should be able to display his ability in these various attitudes of the body, from a military point of view, which requires a considerable blending of physical training, together with skill in the use of the rifle. To thoroughly master each of these positions, those of firing standing, kneeling, prone, and supine (or "back position"), a considerable amount of time and perseverance is required, and no effort should be spared by any one desirous of obtaining the best results in his firing, as all riflemen do, to adapt himself to these positions so completely, that no perceptible change or variation in any position can be detected when firing at either one time or another. When a man, for instance, fires from the knee, upon one occasion holding his rifle in a certain manner and contorting his body in one style of position, and upon another occasion materially varies these details, can it be expected to be otherwise than that under such circumstances the firer should suffer embarrassment in consequence of what appears to him an unaccountable difference in his firing? The same remarks apply to the other varieties of position, the effects of a changing and uncertain attitude only proving more disastrous as the range fired at increases in distance.

No better groundwork can be found for the three positions of firing—standing, kneeling, and prone—than the well-known "Hythe" instructions as to position, as taught in the Army; but every man can more or less modify these rules to suit his own bodily conformation, and time spent in position drill for the purpose of discovering the little points in these positions that appear to be of value in individual cases is time well spent. Several, if not most, of our most successful rifle shots spare no pains in this particular matter, not only in acquiring their positions in firing, but in keeping up such an amount of drill as enables them to retain what has cost so much pains to acquire. With regard to the "back position" in firing, now so universally adopted at the longer ranges, there can be no question as to its great superiority in assisting accuracy of fire, though objections probably exist against its employment at the shorter ranges for military reasons.

Some time ago several varieties of the back position were in use, and occasionally some of these are seen now; but one particular style of this position seems to be likely to supersede the rest.

It is difficult without illustrations to give a thorough idea of such a position, but the one I allude to is that in which, while the right hand grasps the rifle in the usual place, the left hand is applied near the "heel" of the stock, the head of the firer receiving support and steadiness from his seizing the cuff of the left sleeve with his teeth; a band or strap is generally fitted loosely over the sleeve cuff for this purpose. The forward part of the rifle is rested in a fork, formed by the legs of the firer as usual. I may give as an illustration the statement made to me by one of our prominent rifle shots "that to obtain his present kneeling position had cost him nearly two years of practice;" this shows conclusively what pains are and must be taken to acquire perfection in what appears at first sight a very subordinate detail in the art of rifle shooting.

AIMING.—The position of the firer being sufficiently perfect to enable him to hold his rifle steadily when pointed at the target as in the act of aiming, we must next consider a few points bearing on this latter process. Of course in the case of ordinary sights it is impossible for the eye to focus simultaneously, or to see with an equal degree of clearness, the three objects involved in the act of aiming at one and the same time. Any effort to do this will be invariably attended with "blurr," or want of clearness of definition, with one or more of the three objects (these being the bar or notch of back sight, the tip or cone of front sight, and the bullseye or point of aim upon the target). What actually does take place is that the sights being brought into approximate alignment, the eye, by an almost instantaneous change of focus, flashes from point to point, and satisfies the firer of the correctness of his aim. He then should be so steady in his position as to be able to get off his shot without disturbing the laying of the rifle in the slightest degree.

When the eye of the firer is incapable of this power of rapidly changing its focus, the man labours under a serious disadvantage as a rifle shot, whatever his other qualifications in this respect may be. During the last few years it has become the fashion to assist the eye in aiming by the use of colour upon the sights. At first any colours were allowed to be used, and men were to be seen with sights painted partially red, blue, yellow, and a combination of these colours; but it is questionable if the introduction of these primaries offers any substantial advantage over mere black and white. At all events, for various reasons, none but the latter are now allowed, and considerable ingenuity is shown in painting the front sight especially with these tints; annexed is shown three of the more popular styles, but the variations in use are numerous. Fig. 198 is one of the earliest plans adopted, and it will be seen that the "block" is painted white upon its front; while the whole of the cone of the sight, or "barley-corn" as it used to be called, is blackened. The object to be attained by this method of colouring the front sight is the preservation of the angle of elevation, in consequence of the assistance given to the firer in insuring the same amount of fore sight to be taken in when aiming, the cone always being taken in down to the white block, which, when the aim is complete, should be just visible. If it were not for the assistance of the whitened portion of the sight, sometimes in difficult lights some of the block might be included in the aim, thus increasing the angle of fire, and causing a high shot, while the necessity of seeing the white prevents a careless marksman from firing without seeing the cone fully, which would of course reduce the angle and lead to a low shot.

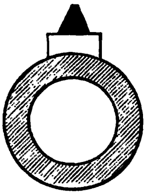
FIG. 198.

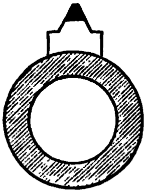
FIG. 199.

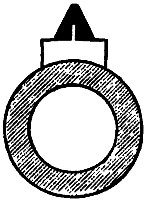
FIG. 200.

Fig. 199 is simply a modification of the former made to suit the "fine sight" style of aiming almost imperative at the longer ranges. In Fig. 200 we find that, in addition to affording a check to variations in elevation, an aid in maintaining the lateral direction is attempted; this is effected by a small white line, often only a dot, which is painted upon the centre of the cone. In aiming the visibility of this line above the bar of the back sight checks off the elevation as in the former examples, while the line on the fore sight is made to coincide exactly with the platina line upon the bar of the back sight, thus obviating what has always been a fruitful source of error in aiming with the plain bar of the military back sight, viz., that tendency to wander with the tip of the fore sight to one or other side of the line upon the bar. Every care should be taken to aim with truth and correctness upon the identical spot of the target that it is decided in the mind of the firer is the proper point of aim under the circumstances, for a slipshod style of aiming is easily acquired and difficult to get out of. Some years ago there were many abstruse theories afloat as to the influences upon the aim in consequence of changes of light caused by passing clouds or other causes. Now, I believe, it has been pretty fairly proved that if a man, during such a change, will distinctly make an effort to *see* his sights and point of aim as in his previous shot no material difference in the position of the shot upon the target will be possible. Of course, if from the approach of darkness or fog, he cannot see what he is doing, good results cannot be expected; but many of the calamities occurring to rifle shots in their scoring, attributed to the evil influence of a change of light, may be much more fairly put down to the man's own careless habit of aiming. One thing does affect the aim to an extent not very generally known, and that is, when, from rapid firing or other causes, the barrel gets hot, the radiated heat is communicated to the air round the front sight, causing, instead of a clear definition of it upon the target, a wavy blurr, and many scores have been spoiled from this cause. While upon this subject it will be well to notice the effect of "mirage" upon aiming with open sights; this peculiar phenomenon is due to a similar cause to the one above mentioned, except that it is the heat radiated from the sun-baked ground, mixed with the moisture that may be raised by evaporation, which produces it, instead of that of the heated barrel, and like the former it causes considerable trouble to rifle shots. Its appearance is well known, and it should be borne in mind that when drifting to the right or left, or streaming upwards, some slight allowance should be made for the effect of its current similar to the allowance made for wind influence. Of course, it does not act upon the bullet as the latter does, but its effect is an optical one, drawing the target in appearance in the direction in which it is streaming, the actual position of the target being a little behind the direction of the stream of "mirage."

LETTING OFF.—The art of discharging the rifle by pressing the trigger without disturbing the aim, would appear at first sight to be an exceedingly simple matter, and one easily acquired, but it is not so. There can be no doubt that perhaps nothing so perplexes the rifle shot during his earlier years of practice more than this particular detail, and perhaps the most difficult part of the business lies in the fact that he is seldom aware of the defect, or to what extent the jerk or tremor imparted to the rifle at the moment of discharge, may interfere with, and, to some extent, upset all the trouble he has taken in aiming, wind allowance, and other preparations for a successful shot. No pains should be spared to get the rifle off in a perfectly undisturbed manner, and much depends upon the position of the hand in firing, that is whether the trigger finger be so disposed as to freely obey the mental intention to fire the arm; if a cramped and awkward grip of the weapon be indulged in, the free and instantaneous action of the trigger finger is interfered with—this of course may be brought about, especially when a man has a small hand, by the "grip" or "hand" of the stock being of a large and awkward shape, as in the Martini-Henry rifle. In such cases it is found to be almost impossible to use the forefinger upon the trigger in a satisfactory manner, and the second finger is used instead, which gives an increased amount of purchase upon the trigger, this finger exerting more power in this position than the other, but some people with practice, get on very well by firing in this manner. Various modifications of the ordinary trigger have been brought forward from time to time, especially those that are so situated as to be pressed by the thumb of the firer; as yet, however, nothing has surpassed the ordinary arrangement. Probably a false idea of what should be the correct manipulation of the trigger has been caused by the use of the phrase "pull off," as describing the act of firing, there should be no *pull* ~~by the barrel~~, but as the aim is completed, the pressure of the finger should gradually increase until the rifle is discharged during a moment of perfect aim. Of course the existence of mechanical defects in the lock action of the weapon, whether they be faults in construction or workmanship, will, if sufficiently pronounced, render it impossible to "let off" in a thoroughly perfect manner, and great practice, care, and mental discipline are required to fully enable the rifle shot always to perform this little but important function properly.

ADJUSTING THE BACK SIGHT for elevation and wind allowance is a most important matter with the rifleman, and could not be performed with the accuracy that modern rifle practice requires if it were not for the aid afforded by a little instrument called a "sight elevator." There are numerous forms of this apparatus, one of the most approved being here illustrated.

It will be seen by examining Fig. 201 that this instrument is constructed so that, by means of a slide to engage with the bar of the back sight and a screw to raise and lower it, the sight bar can be adjusted vertically upon the sight leaf to the desired angle of elevation required. A scale furnished with a vernier is marked upon one edge, as is shown in the engraving. This scale, as I have before explained, is constructed upon the basis of the distance between the front and back sight—in this case as most suitable to the M.H. and most M.B.L. rifles the distance is two feet. The scale is so divided that with its vernier it affords us spaces practically equal to one minute of angle upon a great circle having a radius of two feet, or the distance between the sights; consequently we can move the sliding bar such a quantity as will cause a corresponding value upon the target; thus, if when firing at 500 yards, we raise the bar the amount of one point upon our sight elevator, the bullet should strike *five* inches higher than before upon

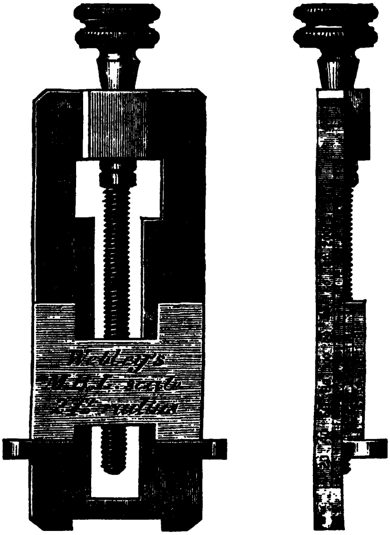

FIG. 201. M.B.L. SIGHT ELEVATOR.

the target. If this process is applied at 1000 yards, the position of the bullet is *ten* inches higher upon the target, and so on at all ranges where the tangent leaf of the back sight is used. This mode of graduating a sight scale affords an easily remembered proportion between the movement of the sight slide and the corresponding difference of position of the bullet upon the target. A farther use can be made of this pattern sight elevator, as in the accompanying illustrations, where it is shown as applied to the sight leaf of a M.H. rifle, so as to mark on the sliding bar the amount of lateral allowance required by a certain amount of side wind.

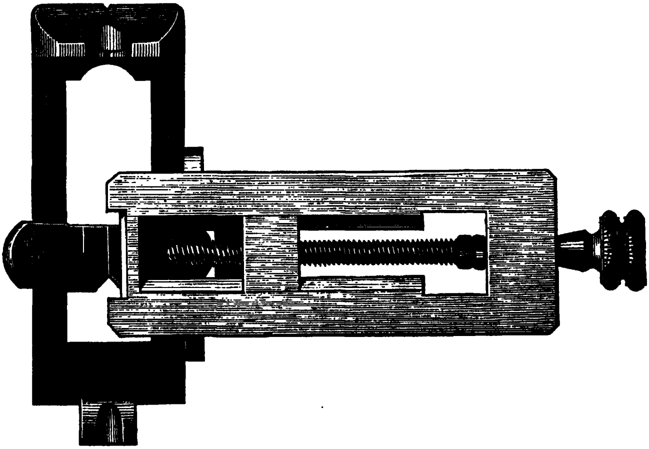

FIG. 202.

If when the sight elevator be applied, as in the drawing, to the sight of a M.H. rifle, and set so that the lower edge of the gauge coincides with the middle line upon the bar, the scale will read about 57 or 60 points as a zero; if it is then set to 39 or 40 it will be found to coincide with the right side line, and at about 77 it will agree with the left-side line, showing that the space usually inclosed between the central and side lines with this rifle is equal to about 19 points on the scale of the sight elevator; but I have shown that these points have a value on the target according to the range at which they may be used, and this value holds good for both lateral and vertical movement; therefore, whatever degree of strength we may estimate the wind as blowing with, we can easily mark upon our bar with the help of this gauge—a line that if our judgment be correct will enable us to continue our aim upon the bullseye. For instance, in the illustration of the sight leaf given herewith (Fig. 203), it will be perceived that an auxiliary wind line has been marked upon the bar midway between the permanent central and side lines; this has required 9 points of movement from the zero given above, and at 500 yards the wind allowance obtainable with such a line would be 5in. × 9 = 45in., or 3ft. 9in.; at 1000 yards, 10in. × 9 = 90in. or 7ft. 6in., and so on at intermediate ranges.

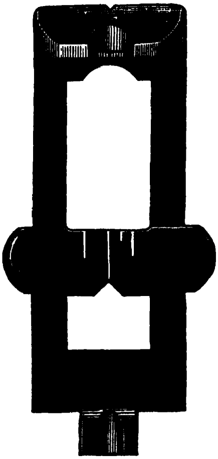
FIG. 203. MARTINI-HENRY BACK SIGHT.

This rule holds good, whatever the distance between the sights of the rifle may be, though the scale must be cut accordingly, the same scale not suiting rifles having their sights any closer together or wider apart than the radius the scale is arranged from.

I herewith give a table calculated some years ago, of the wind allowances in feet upon the M.H. rifle back sight; it is calculated for every 100th of an inch available between the central and side lines, the total space on each side being approximately one-eighth of an inch.

WIND GAUGE ALLOWANCES IN FEET.

| Range. | ·01 | ·02 | ·03 | ·04 | ·05 | ·06 | ·07 | 0·8 | 0·9 | .10 | .11 | ·12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 500yds. ...... | ·62 | 1·25 | 2·14 | 2·50 | 3·12 | 3·75 | 4·37 | 5·00 | 5·62 | 6·25 | 6·87 | 7·50 |
| 600 „ ...... | ·75 | 1·50 | 2·25 | 3·00 | 3·75 | 5·00 | 5·25 | 6·00 | 6·75 | 7·50 | 8·25 | 9·00 |
| 700 „ ...... | ·87 | 1·75 | 2·60 | 3·50 | 4·37 | 5·25 | 6·12 | 7·00 | 7·87 | 8·75 | 9·62 | 10·50 |
| 800 „ ...... | 1·00 | 2·00 | 3·00 | 4·00 | 5·00 | 6·00 | 7·00 | 8·00 | 9·00 | 10·00 | 11·00 | 12·00 |
| 900 „ ...... | 1·10 | 2·25 | 3·37 | 4·50 | 5·62 | 6·75 | 7·87 | 9·00 | 10·12 | 11·25 | 12·37 | 13·50 |
| 1000 „ ...... | 1·25 | 2·50 | 3·75 | 5·00 | 6·25 | 7·50 | 8·75 | 10·00 | 11·25 | 12·80 | 13·75 | 15·00 |

Now that the sliding wind gauge bar is allowed to M.B.L. rifles, of course the graduations thereupon should be upon a similar basis, the sight elevator not applying to them for wind gauge allowance—only to plain sight bars like those upon the M.H. rifle.

It would be possible to carry this chapter to much greater length if the several important features in connection with target rifle-shooting were here investigated exhaustively; but as this volume is now much larger than it was intended to be, I must perforce leave these points until some future opportunity presents itself of ventilating them in the columns of the *Field*. I must conclude this section of my labours by again remarking that many important questions I have touched upon in connection with this subject require fuller and further investigation; and my readers must bear in mind that the columns of the *Field* are always open to temperate discussions relating to any and every thing of interest to the modern sportsman. As an appropriate conclusion to this section, I append a copy of the scoring made in the last great shoot of the Midland Rifle Club, being their annual competition for their Club trophy, shot for with M.B.L. rifles, having military sights and no cleaning out or sighting shots allowed, nor coaching, each member, of course, striving for the coveted prize. I believe this shoot is, up to its date, one of the finest exhibitions of the accuracy of the modern M.B.L. rifle that we have on record; and I am glad that, through the courtesy of the hon. sec. of the club, I am able to give it shot for shot as a standard of excellence that will not probably be easily surpassed at present.

## MIDLAND RIFLE CLUB.

Date, Oct. 6, 1883. *Weather, fine, moist. Light good, fading at 1000 yards. Wind, left rear, moderately fresh, variable at 900 yards. Fifteen shots at each range—shot for shot—no sighting shots.*

| Rifle. | Names. | **800 Yards.** | | | | | | | | | | | | | | | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W. Webley ...... | F. Osborne... | 3 | 5 | 5 | 4 | 3 | 4 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 67 |
| „ ...... | G. H. Hart... | 5 | 5 | 5 | 3 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 3 | 5 | 68 |
| „ ...... | H. Webley ... | 2 | 5 | 5 | 3 | 3 | 4 | 4 | 0 | 2 | 5 | 5 | 4 | 5 | 5 | 5 | 57 |
| „ ...... | R. H. Jones . | R | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 2 | 5 | 5 | 4 | 5 | 64 |
| „ ...... | H. Bates ... | 3 | 4 | 3 | 3 | 5 | 5 | 5 | 2 | 5 | 3 | 4 | 5 | 5 | 5 | 5 | 62 |
| F. Turner ...... | J. Foulkes ... | 5 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 3 | 4 | 5 | 4 | 5 | 5 | 67 |
| „ ...... | T. Turner ... | 3 | 4 | 5 | 2 | 3 | 5 | 5 | 3 | 5 | 5 | 3 | 4 | 3 | 4 | 5 | 59 |
| D. E. Metford ... | J. White ...... | 5 | 4 | 5 | 5 | 5 | 3 | 0 | 3 | 3 | 4 | 4 | 4 | 5 | 4 | 5 | 59 |
| | | **900 Yards.** | | | | | | | | | | | | | | | |
| | F. Osborne... | 3 | 5 | 4 | 5 | 3 | 2 | 5 | 4 | 3 | 5 | 3 | 4 | 5 | 4 | 3 | 58 |
| | G. H. Hart... | 5 | 3 | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 3 | 4 | 4 | 5 | 4 | 3 | 63 |
| | H. Webley ... | 5 | 5 | 3 | 3 | 2 | 3 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 4 | 61 |
| | R. H. Jones . | 3 | 5 | 5 | 5 | 4 | 5 | 4 | 4 | 2 | 5 | 2 | 3 | 4 | 2 | 4 | 57 |
| | H. Bates ... | 3 | 5 | 2 | 5 | 3 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 0 | 61 |
| | J. Foulkes ... | 3 | 4 | 5 | 0 | 5 | 5 | 4 | 5 | 4 | 3 | 4 | 3 | 3 | 4 | 5 | 57 |
| | T. Turner ... | 5 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 3 | 2 | 3 | 4 | 4 | 59 |
| | J. White...... | 3 | 3 | 3 | 5 | 5 | 5 | 3 | 5 | 4 | 2 | 5 | 5 | 3 | 4 | 4 | 59 |
| Aggregate. | | **1000 Yards.** | | | | | | | | | | | | | | | |
| 193 | F. Osborne... | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 68 |
| 188 | G. H. Hart... | 4 | 5 | 4 | 2 | 4 | 4 | 3 | 4 | 3 | 5 | 5 | 3 | 4 | 2 | 5 | 57 |
| 181 | H. Webley ... | 5 | 4 | 4 | 5 | 3 | 5 | 4 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | 63 |
| 178 | R. H. Jones . | 3 | 4 | 3 | 5 | 3 | 4 | 5 | 3 | 3 | 5 | 2 | 5 | 5 | 5 | 2 | 57 |
| 177 | H. Bates ... | 4 | 5 | 3 | 3 | 4 | 3 | 3 | 4 | 2 | 5 | 2 | 5 | 3 | 3 | 5 | 54 |
| 177 | J. Foulkes ... | 3 | 5 | 5 | 4 | 2 | 4 | 0 | 4 | 2 | 3 | 5 | 4 | 4 | 5 | 3 | 53 |
| 175 | T. Turner ... | 3 | 5 | 5 | 5 | 3 | 4 | 5 | 5 | 3 | 3 | 3 | 5 | 3 | 3 | 2 | 57 |
| 174 | J. White ... | 4 | 4 | 4 | 3 | 3 | 4 | 5 | 5 | 3 | 3 | 4 | 4 | 3 | 2 | 5 | 56 |

Signed FRED. A. BIRD, Hon. Sec.

| | | |
|---|---|---|
| Range total ................. | 800 yards ........... | 503 |
| Average individual score... | „ ........... | 62·875 |
| Range total ................. | 900 yards ........... | 475 |
| Average individual score... | „ ........... | 59·375 |
| Range total..................... | 1000 yards ........... | 465 |
| Average individual score ... | „ ........... | 58·125 |

Average aggregate score ......... 180·375.

# GLOSSARY OF TERMS USED IN VOL. II.

**Bore, Large.**—A rifle in which the diameter of the bore is greater than ·577in.

**Bore, Small.**—A rifle in which the diameter is not more than ·577.

**Drop of Bullet.**—The distance between the line in which a bullet is projected and the point to which it is carried down by force of gravity; in other words, the space between the straight line of fire and the curved line of trajectory (see page 131).

**Elevation.**—The extent to which the muzzle of the gun is raised in order to counteract the tendency of the bullet to drop towards the earth. The "Line of Elevation" is the same as "Line of Fire" or "Line of Projection."

**Energy.**—The amount of force or working power existing in a moving projectile (see page 233).

**Express Rifle.**—(See pages 11—28).

**Flight, Line of.**—Same as "Trajectory."

**Flip.**—A term used by Mr. Metford to indicate a peculiar movement of the barrel, which causes the projectile to depart from the line of fire in a direction different from the jump (see pages 224 and 354).

**Initial Velocity.**—A term for which "Muzzle Velocity" is now usually substituted as being more accurate.

**Jump.**—An effect of recoil which causes the projectile to depart from line of fire, in an upward direction.

**Line of Aim.**—The prolongation of a line drawn from the back to the front sight (see page 130).

**Line of Fire.**—A prolongation of the long axis of the barrel (see page 130).

**Magnum.**—A term applied to a rifle carrying an unusually heavy ~~bullet~~.

**Muzzle Velocity.**—The speed of the bullet as it leaves the muzzle.

**Point Blank.**—An obsolete term of indefinite meaning (see page 14).

**Projection, Line of.**—See "Line of Fire" and "Elevation."

**Sight, Aperture.**—A disk with a small hole in it for the sight.

**Sight, Back.**—An addition to the breech end of the barrel, or to the stock, intended to regulate the aim by giving the proper amount of elevation.

**Sight, Fine.**—When only a small part of the front sight is visible (see page 343).

**Sight, Front.**—An addition to the muzzle of the barrel for the same purpose.

**Sight, Full.**—When the whole of the bead appears in the V of the back sight (see page 343).

**Sight, Line of.**—Also called "Line of Aim."

**Trajectory.**—The curved line which the centre of the ball takes after leaving the barrel (see page 130).

**Trajectory Height.**—The distance between the highest point of the trajectory and the line of sight (see page 130).

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EACH FLASK THUS LABELLED.

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BEG respectfully to direct the attention of Sportsmen to the varied and well-known Brands of their manufacture, which, with the traditions and experience of very many years, are yet constantly adapted to the enlarged development of practical science in Guns.

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## GRANULATED.

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WHOLESALE ONLY, AT THE COMPANY'S OFFICES.

## 32, GRESHAM-ST., LONDON, E.C.,

**And to be had Retail and in Cartridges from all Respectable Dealers.**

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**HIGH PENETRATION, WITH LESS SMOKE, LESS FOULING, AND LESS RECOIL THAN BLACK POWDERS.**

It was used by all the Prize Winners at the International Pigeon Shootings 1881, 1882, and 1883.

### SCHULTZE GUNPOWDER versus BLACK GUNPOWDER.

*Competition at the Gun Club, July 5th,* 1882, *for a Cup and Sweepstakes.*

CONDITIONS—Those using Black Powder allowed to stand one yard nearer than their respective Handicap distances.

**RESULT.**

1st. Mr. E. B. Cunliffe, 29 yards.
"**Schultze**" Powder...... 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1
2nd. Mr. Pearce, 28½ yards.
"**Schultze**" Powder...... 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 0
3rd. Mr. Turner-Turner, 31 yards.
"**Schultze**" Powder............................................... 1 1 1 1 1 1 1 1 0

There were other Competitors.

**N.B.—There is only one quality of**

## "SCHULTZE GUNPOWDER."

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**Each Canister bears a Label with Trade Mark as above.**

# HOLLAND & HOLLAND'S

## '360 BORE

# ROOK AND RABBIT RIFLES.

---

## The following Diagrams were made by Mr. Horatio Ross, with one of Hollands' '360-Bore Rabbit Rifles.

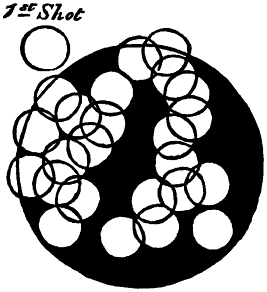
### Extract from letter received with the Diagrams.

"ROSSIE LODGE, INVERNESS,
"June 3, 1882.

"GENTLEMEN,—I have much pleasure in sending you some Diagrams, made by me, with your little Rabbit Rifle a few days since. I have never seen better shooting made (with a Sporting Rifle) in this country. . . . . You are welcome to make any use of the Diagrams. I shot sitting, using a table rest for my elbows.

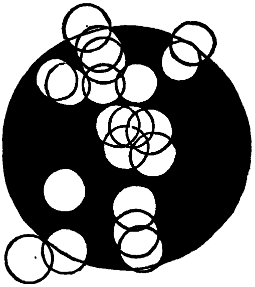
"I am, Gentlemen, yours truly,
"(Signed) HORATIO ROSS."

RANGE 86 YARDS.



¼-SCALE.

RANGE 100 YARDS.



¼-SCALE.

**See also letter, "Field," Aug. 12, 1882:**

"I have killed, with one of Hollands' ·360 Six Guinea Rifles, rabbits, hares, rooks, seal, and about 35 red deer, at distances up to 150 yards. I have killed all the deer dead with the exception of four, they went only some 300 yards. . . . . "ALINE."

These Rifles are more powerful, and are sighted to a longer range than the ·295 (see previous page), and are specially adapted for

## SEAL AND RABBIT SHOOTING.
## BUCK SHOOTING IN INDIA.
## KANGAROO, &c., SHOOTING IN AUSTRALIA.

They are perfectly accurate up to 150 yards range. Shooting may be tested before purchase at our Private Range. Rifles exchanged free of charge if not approved of.

## PRICES 5 TO 10 GUINEAS.

HAMMERLESS, 10 guineas. DOUBLE-BARRELLED, from 20 guineas.

**Orders from strangers should be accompanied by Remittance or London reference.**

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## GUN AND RIFLE MANUFACTURERS,

BY SPECIAL APPOINTMENT TO H.M. THE KING OF ITALY,
And Winners of all the "Field" Trials, 1883.
98, NEW BOND STREET, LONDON, W.

# HOLLAND & HOLLAND'S DUCK GUNS.

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## NEW C.F. HAMMERLESS PUNT GUN "THE LONDON."

**Steel Barrel, bored out of the solid, fitted with Patent Extractor.**

See letter from E. T. BOOTH, Esq., in the "Field," Aug. 27, 1881:

"The Punt Gun (1½in.) I obtained from Messrs. Holland proved itself far superior to what I could have anticipated. The shooting is, I believe, far stronger than that of any gun I had previously used. . . . . Although it had been exposed to a good deal of rough work and salt water, the action worked perfectly the whole season, and never on any occasion gave the slightest trouble, neither did a single cartridge ever stick in the barrel."

The Editor of the "Field" writes (see "Field," Feb. 18, 1882):

"In Punt Guns this firm (Holland and Holland) is now *facile princeps*. Their steel breechloader being generally admitted to be the best in the market. These guns are fitted with loop for rope breeching, and with Hawker's spring arrangement, or with the Booth recoil block and buffers from drawings supplied by E. T. Booth, Esq.

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## 4-BORE C.F. GUNS.

**Specially bored for Large Charges, killing to 150 yards**

See letters to the Editor of the "Field:"

"SIR,—Having heard that in a December number of your paper there is an inquiry as to the range of large bore shoulder duck guns, he might like to know that I have killed birds at 150yds. range with a 4-bore gun made by Messrs. Holland, of New Bond Street. With the recoil heel-plate there is no recoil to hurt the shoulder. Signed "ELCHO."

"SIR,—In answer to J. O. respecting shooting of 4-bores, I can with confidence recommend him to go to Messrs. Holland, of Bond-street, for I have shot with many 4-bore guns, and certainly have never found any equal to the one built for me by that firm. It is a wonderful killer, as well as being a particularly light and handy gun; charge, 9dr., and wire cartridge, killing at 100yds., and frequently at much greater distances. I am so pleased with the gun that I am having a punt gun built by the same makers. Signed "ALEX. HATFIELD.

"Morden Hall, Morden, Surrey."

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**Also 8-Bore Single and Double Barrelled HAMMERLESS GUNS and Short Barrelled 10-Bore CRIPPLE STOPPERS.**

*The above Guns are fitted with Recoil Heel-plates, Pistol Grip, &c.*

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# "CLIMAX"
# SAFETY HAMMERLESS GUN.

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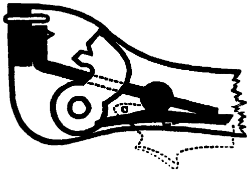

CLIMAX SAFETY, showing block intercepting the fall of the hammer if jarred off.

Fitted with the New Patent Gas Check, preventing any escape of gas into the locks.

One of the most perfect weapons yet made.

Being exceptionally strong in the action, they are especially adapted for any size up to 4-gauge, and are chambered for the New "Perfect" Brass Shell when required.

## NEW TOP-SNAP EJECTOR
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EJECTING THE EXPLODED CASE AFTER FIRING.

**Prices: First Quality, 35 guineas to £45. Second Quality, from £25.**

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# BREECHLOADING GUNS.

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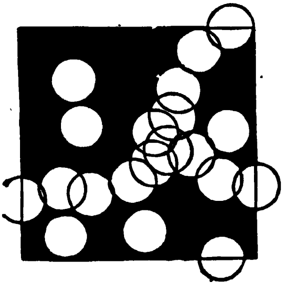
# WINNING ·295-GAUGE ROOK RIFLE,

## SEMI-SMOOTH BORE NON-FOULING RIFLING

(REGISTERED).

ANY NUMBER OF SHOTS MAY BE FIRED WITHOUT CLEANING OUT.



FULL SIZE, 50 YARDS.

**AUTHENTICATED DIAGRAM of the 295-Bore WINNING RIFLE in the great "FIELD" Rifle Trial, London, October, 1883.**

Twenty Shots at 50 yards WITHOUT CLEANING OUT, all in a 1¼in. square. Every shot would have struck a half-crown piece.

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"An unequalled performance." — See *The Field*, Oct. 20, 1883.

"Certainly the best shooting we have ever seen."—*Field*.

## HOLLANDS' NEW PATENT ·295 HAMMERLESS ROOK RIFLE, "THE ROSS."

"A Rook and Rabbit Rifle which completely fulfils all the conditions required by the Sportsman, and may be considered an absolutely perfect weapon."—*Field*, April 14.

MR. HORATIO ROSS writes: "Your Rifle is the most accurate weapon I have ever had in my hands."

**Each Rifle guaranteed in every way, and may be shot at our Private Range at Kensal Green before Purchase.**

**PRICES 5 TO 10 GUINEAS. "ROSS" HAMMERLESS, 10 GUINEAS. DOUBLE-BARRELLED, from £25.**

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**With Special Non-Fouling Rifling, giving great accuracy with the flattest trajectory obtainable.**

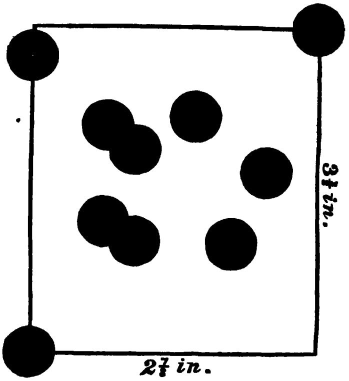

**DIAGRAM MADE BY THE WINNING ·500 BORE**

## Double Express RIFLE.

Range, 100yds. Charge, 5drs.
Trajectory, 1½in.
Mean Deviation, 1·09.
Striking Energy, 3134 foot-lbs.

**PRICES, BEST QUALITY, FROM 45 to 55 GUINEAS.**
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**„ THIRD QUALITY, FROM 30 GUINEAS.**

**DEER STALKING RIFLES, ·400 AND ·450 BORE.**

VISCOUNT MANDEVILLE writes:—"I shot with your Express all the season at Arran, and out of nineteen stags I fired at I got eighteen. It is the most accurate Rifle I ever handled. . . . ."

**BAKER ·577 EXPRESS DOUBLE RIFLES (6-DRS.),**

MAY BE USED WITH A SPHERICAL BALL FOR DEER SHOOTING, OR WITH EXPRESS OR SOLID BALL FOR BIG GAME.

SIR SAMUEL BAKER writes:

"Dear Sir, "Jubblepoor, May 20, 1880.

"I have just returned from a month's trip in the jungle, and can give you the practical results of the ·577 6-drs. Rifle you made for me. *Without exception it is the best Rifle I ever possessed.* I have only had three shots at tigers—they never moved their own length from the moment of receiving the bullet. . . . ."

**ALL RIFLES MAY BE TESTED BEFORE PURCHASE.**

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**GUN AND RIFLE MAKERS,**

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AWARDED 3 MEDALS INTERNATIONAL EXHIBITION, CALCUTTA, 1883-4.

CHARLES LANCASTER,

INVENTOR AND PATENTEE OF THE

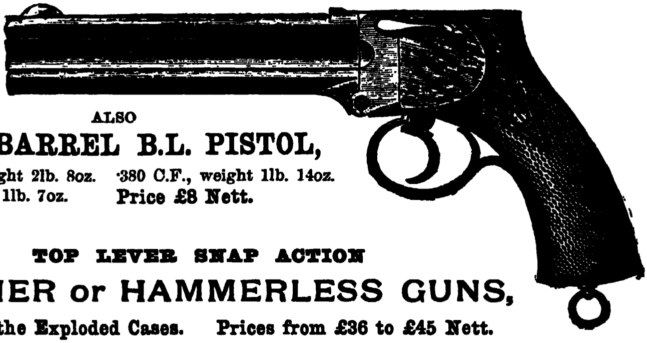
FOUR-BARREL

B.L. HAMMERLESS GUN,

Weight 7lb. 4oz., and

EXPRESS RIFLE,

Weight 10lb.



ALSO

FOUR-BARREL B.L. PISTOL,

·455 C.F., weight 2lb. 8oz. and 1lb. 7oz. ·380 C.F., weight 1lb. 14oz. Price £8 Nett.

TOP LEVER SNAP ACTION

HAMMER or HAMMERLESS GUNS,

Ejecting the Exploded Cases. Prices from £36 to £45 Nett.

The "COLONIAL" Quality 12-bore, Breech-loading, Top Lever, Snap Action GUN. Plainly finished, but good sound work. Price £20.

*Coloured Illustration sent on application.*

Also "COLONIAL" Quality HAMMERLESS GUN, £27.

Strong Black Canvas Case, without fittings, £1 15s. Strong Black Canvas Case, with fittings, £3.

TERMS, CASH WITH ORDER. DETAILED PRICE LISTS ON APPLICATION.

DEER FORESTS, SHOOTINGS, and FISHINGS to LET.

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ESTABLISHED 1826.

[P.T.O.

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INVENTOR OF THE

# NON-FOULING SMOOTH OVAL-BORE

FOR

# EXPRESS

**('360, '400, '450, '500, and '577). Prices from £36 to £56 10s. Nett.**

# ROOK AND RABBIT

**('295, '320, '360, and '380). Prices £5, £8, and £10 Nett.**

# HAMMERLESS ROOK AND RABBIT RIFLES, £10 NETT.

AND

# MINIATURE MATCH RIFLES,

**Prices £8 plain; £10 with orthoptic sights.**

---

**The following Letters are some of those that have appeared in "The Field," and are a sample of those that I am constantly receiving from all parts of the world:**

## THE LANCASTER OVAL-BORED EXPRESS RIFLE.

"THE FIELD," AUG. 6, 1881.

SIR,—A friend of mine has called my attention to the correspondence which has taken place in "The Field" regarding the merit of Charles Lancaster's oval-bored Express rifles.

I have shot in various parts of the world during the last thirty-five years, with all the new improvements made by the best rifle makers in the United Kingdom, and I have no hesitation in affirming that, for sporting purposes, the Lancaster double breechloading Express is the best rifle which exists. *In saying this, I do not wish to disparage other makers whose rifles are also very near perfection; but that Lancaster beats them I am convinced, and for the following reasons:*

*The great object to be obtained* in a sporting rifle is accuracy, with the flattest possible trajectory up to, say, 250 yards. This is only to be obtained by a high velocity for the ball during its passage over that distance. The initial velocity of the ball depends upon the burning of so much powder in the barrels. The accuracy of the ball's flight depends upon its rotary motion. That rotary motion is imparted by the grooving of the rifle in most cases, and by the oval-bore in the Lancaster case.

With a given amount of powder, the smaller the resistance to the ball in passing through the barrel the greater will be its initial velocity on leaving it, and the less will be the recoil of the rifle. The grooves on the inside of a barrel naturally prove a greater resistance than a smooth surface, therefore the smooth surface of a Lancaster barrel gives less resistance than any grooved barrel, and for a given amount of powder the initial velocity of the ball must be greater and the recoil less.

The ball having left the rifle, the great object is to keep up its velocity to the highest possible pitch for the sake of a flat trajectory, and to keep up its rotary motion for the sake of accuracy. The retarding forces opposed to the attainment of this object are the resistance of the air and the friction of the air on the rotating ball. Therefore the smoother the ball the less friction or retardation there will be.

In the case of the Lancaster oval-bore, the ball leaves the barrel with a smooth surface, while in grooved rifles it is more or less jagged and indented by the grooves. Therefore, with a given amount of rotary motion on leaving the barrel, the Lancaster ball will keep up that motion longer than a ball from a grooved barrel, and would therefore give greater accuracy along the whole length of its flight.

### "The Field," May 27, 1882.

"Bison" asks for information with regard to oval smooth-bore rifles. I have just returned from a shooting trip to Ceylon. I took out one of Lancaster's ·500 smooth oval-bore double hammerless Express rifles. I found that it was very accurate, and made better penetration than other rifles on the grooved system of rifling, in some of which the weight of the bullet was not so well regulated to the charge of powder. It never got leaded, and was easy to clean, and, though roughly used in a hot, damp, trying climate, never got out of order; and by using a hollow or solid bullet, as the case required, I was able to kill every sort of game with it, from peacocks to elephants. . . . . . H. N. B. Good.

The Priory, Berwick St. John, Wilts, May 23.

## "FIELD" TRIAL OF OVAL-BORE EXPRESS.

In "The Field" of Feb. 17, 1883, the Editor writes as follows:

On Monday morning last, after several adjournments owing to the weather, we proceeded to Mr C. Lancaster's ground at Wormwood Scrubbs, with a view to witness a trial of one of his oval-bores, which we have been requested to do by several correspondents. The morning was by no means favourable to good shooting; indeed, the wind was so high as to tax the strength of the shooter in keeping the barrel steady. It blew from the right front of the range, and occasionally with great force, with a few drops of rain, which necessitated an umbrella being held over the front sight.

The rifle was a single ·500 oval-bore, with Mr. Field's action, weight 10lb. 6oz., length of barrel 26in. We began with a series of ten shots, with 160gr. C. and H. No. 6 and 600gr. pure lead bullet, having a cavity in front, 1-16th in. in diameter, and half the depth of the bullet distance 100 yards.

First eight shots were grouped in a space of 5in. by 4in., the ninth 1½in., and the tenth 4in. to leeward of the group.

Second series.—Powder, 160gr.; lead 440gr. pure soft lead, with a cavity in front filled with wax. Eight shots were fired, of which the first six were in a group 3½in. square; the seventh was 6in. from the centre of this group to the top right. Mr. C. Lancaster, having previously stated that he was hitherto making no allowance for wind, now declared to make a bull (1½in.) by allowing for wind, and did so.

This performance, even without taking into consideration the gusts of wind which were blowing, is a very good one, but, making allowance for this drawback, our readers will, we think, agree with us that it was highly satisfactory to Mr. C. Lancaster, who, besides being the maker, shot the rifle himself.

The initial velocity of the heavy bullet was about 1620ft. per second, and that of the lighter one 1750ft., as taken by the chronograph belonging to Messrs. Curtis and Harvey; consequently, there should be a difference of about 1in. in the elevation of the two at 100 yards on this calculation, yet in practice, though Mr. C. Lancaster took the same sight throughout, they were as nearly as possible alike, which can only be accounted for by the greater "jump" given by the heavier ball. *This is a very interesting fact in support of the "jump" theory.*

## NOTES ON RIFLES.

### "The Field," March 17, 1883.

Sir,—Having read with much interest the various letters that have appeared in your columns respecting rifles for deer stalking, I beg to hand you return of my own shooting during the past season, with one of Charles Lancaster's Smooth Oval-bore Express Rifles, ·450 bore, double barrel.

The first day of the season I killed five stags—viz., two rights and lefts, and one single. I then went on killing without a miss till I reached twenty-five, and in the afternoon of one day I killed a right, and left and a single. I then killed on up to my fortieth, when I made two misses, and then to fifty-five without a miss. I killed seventeen stags in four days, bonâ-fide stalking.

This finished the season for stags. In due time I began the hinds, and killed forty-five without a miss.

I should mention that all these slain beasts were not picked chances, but that I took them as they came at ranges varying from 40 to 200 good yards, the beasts in all positions and paces; *i.e.*, standing in every position, walking, lying down, and galloping, and all sheer stalking.

This speaks volumes for the accuracy of the rifle, and I believe it is the best that ever was made.

In conclusion, I trust that my record may be the means of showing stalkers that a rifle can be built to give such grand performances, and with little or no recoil to the shooter, owing to the smooth interior of the barrel. Frank Morrison.

8, Cromwell-houses, South Kensington, S.W., March 14, 1883.

# CHARLES LANCASTER

Begs most respectfully to inform his Patrons and Sportsmen that the following are his CASH PRICES for

**CARTRIDGES**

for this Season, viz.:

**12-Bore C.F., 3drs., 1⅛oz., at 10s. per 100.**

**16-Bore C.F., 2¾drs., 1oz., at 9s. 6d. per 100.**

**20-Bore C.F., 2drs., ¾oz., at 8s. per 100.**

Eley's Best Cases, loaded with Curtis and Harvey's best powder, four best wads, and hard shot, thin packing cases included.

**Schultze or "E.C." Powder 1s. per 100 extra.**

Stout Cases FOR RAIL, 6d. first 200, adding 2d. each additional 100.

N.B.—ALL ORDERS MUST BE ACCOMPANIED BY A REMITTANCE.

Packed in extra Stout Packing Cases, lined with tin, for India, at 10s. per 1000 extra.

C. L. delivers Loaded Cartridges at Bombay, Madras, or Kurrachee, at the following rates for freight, plus the price of Cartridges and Packing Cases, viz.:—

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,000 at ...... | £2 | 2 | 0 | 5,000 at ...... | £3 | 0 | 0 | 9,000 at ...... | £4 | 15 | 0 | 17,000 at ...... | £7 | 0 | 0 |
| 2,000 at ...... | 2 | 10 | 0 | 6,000 at ...... | 3 | 10 | 0 | 10,000 at ...... | 5 | 0 | 0 | 18,000 at ...... | 7 | 5 | 0 |
| 3,000 at ...... | 2 | 15 | 0 | 7,000 at ...... | 4 | 0 | 0 | 15,000 at ...... | 6 | 0 | 0 | 19,000 at ...... | 7 | 10 | 0 |
| 4,000 at ...... | 2 | 17 | 6 | 8,000 at ...... | 4 | 10 | 0 | 16,000 at ...... | 6 | 10 | 0 | 20,000 at ...... | 7 | 10 | 0 |

N.B.—Cartridges cannot be shipped direct to Calcutta, only *via* Bombay.

Insurance charged at the rate of ONE per cent. extra.

C. L. begs to draw the attention of Sportsmen to the following figures, giving a return of the Cartridges he has supplied, viz.:

**89,538 in 1880.**

**322,222 in 1881.**

**442,263 in 1882.**

**505,664 in 1883.**

Clearly demonstrating that his Cartridges are yearly gaining in favour, owing to the superior quality of materials used, and the excellence and regularity of the loading.

LOADING ROOM OPEN TO INSPECTION AT

**151, NEW BOND STREET, LONDON, W.**

DETAILED PRICE LISTS ON APPLICATION.

**ESTABLISHED 1826.**

[SEE PREVIOUS PAGE.

# IMPROVED HAMMERLESS GUN,

**With Rigby's Patent Vertical Grip and Safety Bolting.**

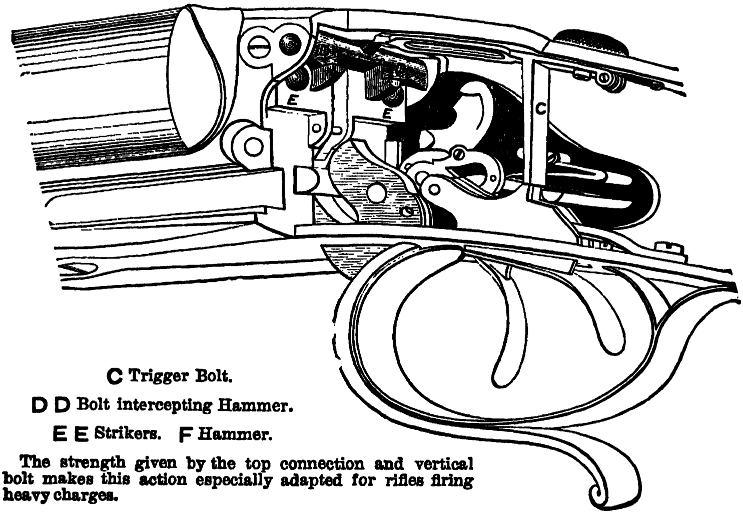
## A SPECIAL MAKE OF STEEL BARRELS.

The Editor of the *Field* in his report of the Gun, January 7, 1882, says:

"In this action all our ideas are carried out to the fullest extent."

"Altogether we consider this the best safety bolt we have seen."

"In Mr. Rigby's Gun the action is as strong, or even stronger, than any of its rivals, the barrels being kept down by the well-known Purdey bolt, and the spring at the angle prevented by a top connection, into which travels upwards a perpendicular bolt similar to that designed by us, but improved upon in a simple manner by leaving the metal of the body intact between it and the barrels, by which it is well supported as if it were a part of the action itself."



**C** Trigger Bolt.

**D D** Bolt intercepting Hammer.

**E E** Strikers. **F** Hammer.

The strength given by the top connection and vertical bolt makes this action especially adapted for rifles firing heavy charges.

## RIGBY'S EXPRESS RIFLES.

Celebrated for their Killing Power, Accuracy, and First-class Workmanship, insuring Durability.

**Gauges ·577, ·500, ·450, ·400, ·380; Weights from 11lb. to 5lb.**

The Annual Sportsman's Contest in India was won with Rigby's ·450 Double Express the last three years.

## BREECHLOADING, MATCH, MILITARY, AND EXPRESS RIFLES WITH RIGBY'S IMPROVED ACTION.

---

**ALL SPORTING NECESSARIES SUPPLIED.**

---

**PRICE LISTS, &c., ON APPLICATION TO**

## JOHN RIGBY & CO.,

**24, Suffolk-St., Dublin; and 72, St. James's-St., London, S.W.**

# J. & W. TOLLEY'S
# "STANDARD"
# HAMMERLESS GUN.

**Opening with the Weight of its own Barrels.**

Fitted with Patent Intercepting Safety Bolts, Blocking Bolts, Triggers, and Tumblers, Gas-check Strikers, preventing the escape of gas into the locks, ordinary Side Locks, which may be easily removed for cleaning.

**From "WILDFOWLER," May 22, 1884.**

**" Messrs. Tolley have made me this season a double hammerless 12-bore short-barrelled for rabbit shooting in very thick covert, and this gun has given me the utmost satisfaction. It is one of smartest guns I have ever used, and I have shot admirably well with it."**

**Price £13. 13s., £15. 15s., £17. 17s, £20, £25, £30, & £35,**

## LONG-RANGE WILDFOWL GUNS.

**Guaranteed performance of 10-Bore at 100 yards.**
**" " " 8 " " 120 "**
**" " " 4 " " 150 "**

**PRICES AND FULL PARTICULARS ON APPLICATION.**

## J. & W. TOLLEY,

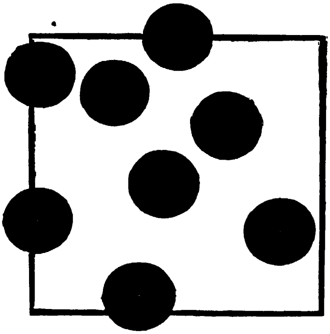
**MAKERS BY SPECIAL APPOINTMENT TO THE PERSIAN ROYAL FAMILY,**

PIONEER WORKS, BIRMINGHAM,
AND
1, CONDUIT-ST., REGENT-ST., LONDON.

# J. and W. TOLLEY'S
# EXPRESS AND BIG-GAME RIFLES.

## OUTFITS FOR BIG-GAME EXPEDITIONS.

All our Rifles are bored on our non-fouling rifling system, giving the greatest accuracy with the flattest trajectory yet obtained.



AUTHENTICATED

DIAGRAM

OF

·450 DOUBLE EXPRESS,

At 100 Yards.

8 SHOTS WITHOUT CLEANING OUT.

Target 2$\frac{13}{16}$ × 2$\frac{6}{16}$.

**From Rev. C. J. Todd, R.N.**—H.M.S. "Euryalus," Tricomalie, Ceylon, Feb. 5, 1883.
"I was delighted with the 8-bore Double Rifle, killing with it five big elephants, four of them with a single ball each. The accuracy is also very great. I shot a buffalo bull at 120 yards right through the neck, which, with his head, was the only part visible. I missed with the second shot, but with a third shot at 150 yards shot him dead through the heart."

**From A. H. Macartney, Esq**.—Newera Elliya, Ceylon, April 25, 1882.
"The 12-bore 'Forsyth' Rifle you sent me was an excellent weapon; none could be better. It did such execution as has never before been equalled. The first time I went out I saw three rogue elephants of enormous size; one shot sufficed for each of them. Then I went out with Lieut. Hannay, R.E., now in England. We saw twenty-one elephants, and killed them all between us, fourteen falling to your rifle. Once it saved our lives, a charging rogue falling dead to it within six feet of where we stood."

**From B. W. Wise, Esq.**—Doolahat, N. Lakimpur, Assam.
Messrs. J. and W. Tolley, Birmingham.
"I have much pleasure in informing you of the safe arrival of the 4-bore rifle. I tried it to-day, firing three shots out of each barrel, and at 40 yards I put the six bullets in a small envelope, and at that distance I will put as many bullets into an envelope as I can with my ·500 'Express.' I must certainly give you credit for the splendid weapon you have built me. I used no rest when I fired it, and the recoil (with Anti-recoil Pad) is no more than that of a ·500 'Express.'"

Express double, ·400, ·450, ·500, and ·577 bore, £25.

| | | | |
|---|---|---|---|
| 12-bore, double ... ... | £25 | 8-bore, double ... ... | £35 |
| 10-bore, double ... ... | £28 | 4-bore, double ... ... | £45 |

**Specimens, Diagrams, Drawings of Trajectories, Testimonials, &c., on application.**

# J. and W. TOLLEY

(Makers, by special appointment, to the Persian Royal Family),

**Pioneer Works, Birmingham, and 1, Conduit-st., Regent-st., London.**

# BLAND'S SPECIAL RIFLES.

## NEW HAMMERLESS SELF-EXTRACTING

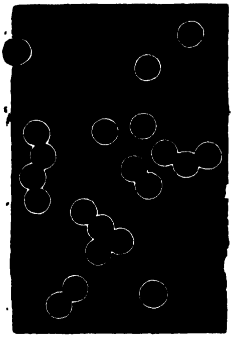
## ROOK & RABBIT RIFLE

In ·230, ·300, and ·360 Bores.

PRICE 10 GUINEAS.

SIMPLICITY OF ACTION. ACCURACY OF SIGHTING.

SPECIAL NON-FOULING RIFLING.



SCALE: ONE-HALF SIZE.

Authentic Diagram of 21 consecutive shots made with the above Rifle, ·360 bore, at 100 yards, WITHOUT CLEANING.

**Also a SPECIAL RIFLE, on the same system, prepared expressly for the Colonies; ·440 bore, using the Winchester cartridge, and sighted to 250 yards.**

Price 10 Guineas.

The Editor of "Land and Water," before whom this Special Rifle was recently tested, in his issue of April 12 last, writes: "NOT ONE SHOT WOULD HAVE MISSED A ROOK, AND THIS, AT 250 YARDS, IS ADMIRABLE WORK."

## BLAND'S

## SELF-EXTRACTING ARMY REVOLVER.

CALIBRE ·455.

Price £2. 17s. 6d.

"The Field," of March 24 last, says: "We have tested this revolver with nearly one hundred rounds, without fouling so as to create any difficulty in manipulation. With regard to accuracy, WE HAVE MADE EXCELLENT PRACTICE WITH IT: that is to say, AS GOOD AS WITH ANY REVOLVER WHICH WE HAVE YET TRIED."

# "THE CAPE GUN,"

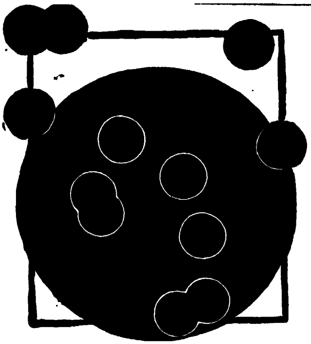
## A RIFLE AND SHOT GUN COMBINED.

**·577/450 Henry Rifle, and 12-bore Shot.** | **·450 Express Rifle, and 16-bore Shot.**
**·500 Express Rifle, and 12-bore Shot.** | **·400 Express Rifle, and 20-bore Shot.**

## PRICE 16 GUINEAS.

**The "Field" of Oct. 13, 1877, says of the "Cape Gun."**

"Selecting one at random from stock, we tried the rifled barrel, first at seventy, and afterwards at 100 yards, from an ordinary rest, and were able to PUT BALL UPON BALL AT BOTH DISTANCES, so that the truth of its shooting from the rifled barrel is good enough for any purpose, and, indeed, CANNOT BE EXCELLED EVEN BY THE MOST EXPENSIVE RIFLE IN THE MARKET."



Authentic diagram of 12 consecutive shots made with one of BLAND'S EXPRESS DOUBLE RIFLES, ·500 bore, each barrel being used alternately.

Distance, 100 yards.

Scale, one half size.

# EXPRESS DOUBLE RIFLES,

## ·360, ·400, ·450, ·500, and ·577 Bores. 20 GUINEAS.

## TESTIMONIALS.

**From H. Jones Bateman, Esq., Kheri, Oudh, India, Aug. 8, 1879:**

"I have every reason to be perfectly satisfied with the ·500 Express you sold me three years ago. It compares favourably with rifles costing double the price."

**From T. Foljambe Hall, Esq., Masonic Hotel, Grahamstown, South Africa, May 18, 1882:**

"I have delayed hitherto in writing to you about my rifle, as I wished to give it a thorough trial. I have now done so, and can truly say that it has more than fulfilled my utmost expectations. At all ranges I have found it most accurate, the action has withstood every test of weather, and the workmanship leaves nothing to be desired."

**From R. Percy Pinder, Esq., Indian Forest Department, Nov. 8, 1882:**

" . . . My rifle C.F. ·500 Express, built by you, is a magnificent weapon; indeed I have never used one that I like so well."

**From Major Wilbraham Taylor, Rifle Brigade, Belgaum, Bombay Presidency, Nov. 21, 1883:**

"I have received the ·500 Express Rifle, and am much pleased with its shooting. It is a good serviceable weapon, and just what I wanted."

*N.B.—Any of the above can be delivered free in either of the large ports of India or of British Burmah, in a tin-lined case, for £1 1s. more.*

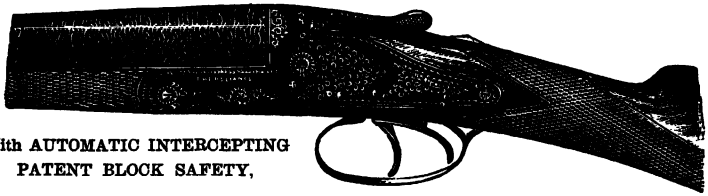
# T. BLAND AND SONS.

ADDRESSES:

106, STRAND, LONDON, W.C. (Opposite Exeter Hall);
62, SOUTH CASTLE STREET, LIVERPOOL;
And 41, 42, and 43, WHITTALL STREET, BIRMINGHAM.

# ADAMS and CO.'S

## New Hammerless Gun "THE RELIANCE."



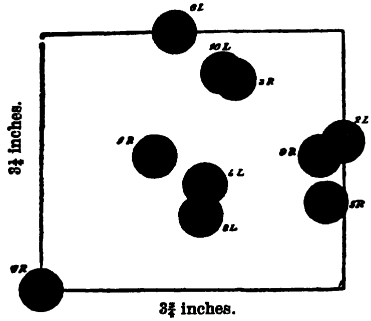
With AUTOMATIC INTERCEPTING
PATENT BLOCK SAFETY,

By which the Hammers remain perfectly blocked until the moment of pulling the triggers. Absolutely safe against accidental discharge.

## EXPRESS DOUBLE RIFLES, FROM ·360 TO ·577 BORE.

The diagram given below is a *fac simile* (reduced) of the shooting of one of our ·577 Express Double Rifles, and published in the "Field," July 18, 1883. It was shot from Mr. Jones's machine rest in the presence of the Editor of the "Field."

The Editor remarks: "To our great astonishment we got the diagrams made, which we publish this week, in one case from a ·450 bore, recently made by a well-known firm, and in the other from a ·577 bore, made by Messrs. Adams, of Finsbury Pavement, about a year ago, since which it has been used in India by a well-known sportsman. The ·577 diagram is a most excellent one, beating very considerably repeated trials from the shoulder. From the shoulder, the best diagram made was 6in. × 4¼in. From the rest, the annexed splendid diagram was obtained; the shots are numbered R. and L., and it will be seen the group is quite free from any kind of uniformity, the shots being spread indiscriminately."

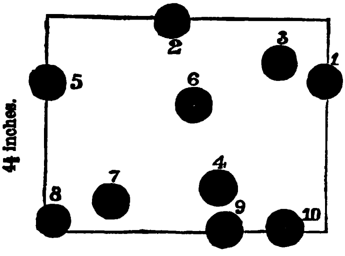


10 Consecutive Shots at 100 Yards.

### "FIELD" RIFLE TRIAL AT WIMBLEDON.

October 6th, 1883.

*Fac simile* (reduced) of diagram made from the shoulder with Adams and Co.'s ·500 bore Express Double Rifle, at 150 yards, being the best diagram of the class made at that range.



### ADAMS & CO.'S
### MARTINI-ZELLER PATENT RIFLES.

For Rook, Rabbit, and Small Deer Shooting.

Self Cocking. Ejects the fired cartridge clear of the rifle. Accuracy of shooting unsurpassed.

·380 Bore, price £3; ·360 Bore (extra quality), price £4.

### HAMMERLESS AND HAMMER EJECTOR ROOK RIFLES, ·300 Bore and ·360 Bore.

GUN, RIFLE, AND REVOLVER MANUFACTURERS,

**32, FINSBURY PAVEMENT, LONDON, E.C.**

PRICE LISTS POST FREE.

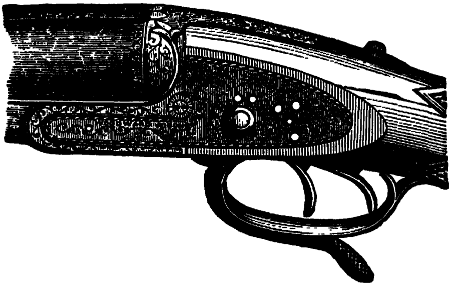
# JAMES WOODWARD & SONS.

PATENTEES AND MANUFACTURERS OF

## "THE AUTOMATIC"

## Patent Hammerless Safety Gun,

FOR WHICH A PRIZE MEDAL WAS AWARDED AT THE PARIS EXHIBITION.



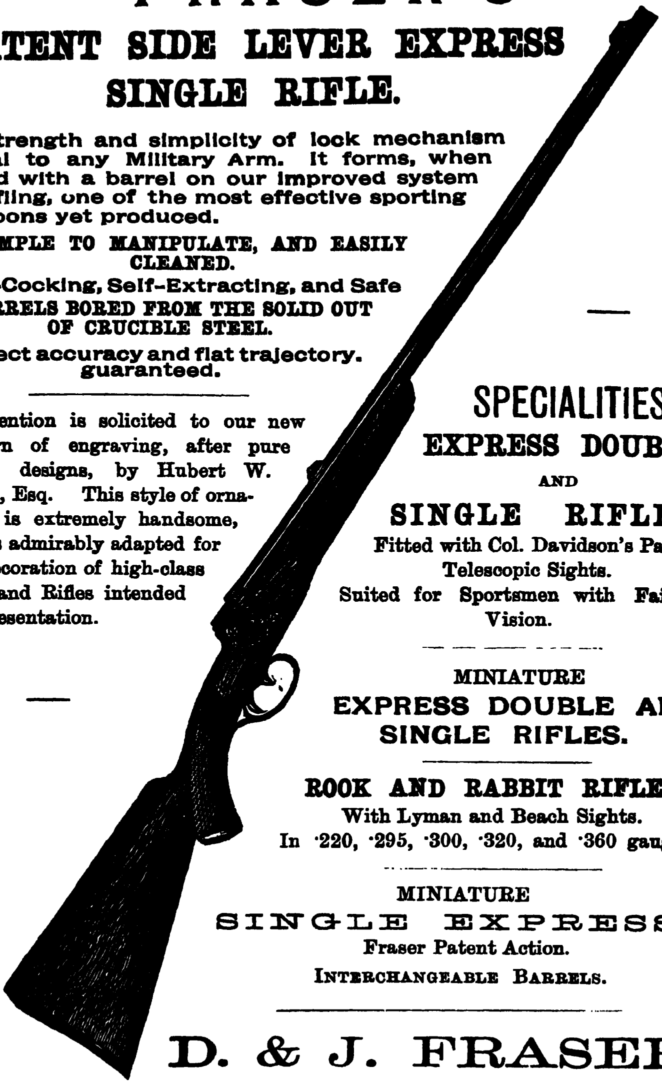
HAVING had six years' experience with perfect success, we have the greatest confidence in recommending our Hammerless Safety Gun to our clients and their friends.

One of the numerous advantages is that the same locks and actions are used as in ordinary bar guns, with the exception that the hammers are inside instead of out; in other respects the outlines are precisely the same. The hand lever centred on the trigger plate has a lifting bar hinged to it, which bears on the arms projecting from the tumblers. It raises the locks, and at the same time moves a safety bolt over the ends of the triggers, and one in front of each hammer, so that, should the lock be jarred off by a fall, the safety bolt in front of the hammer would catch it in the throat immediately at starting, rendering it impossible for any accidental explosion to happen. The construction of the lifting bar, hinged on the hand lever, is so arranged that very little force is required to raise the locks, consequently the same weight main-spring can be used as in a gun with outside hammers, avoiding any chance of miss-fires so often complained of in hammerless guns

Our great safety point is that on opening the gun *all parts are bolted*, and, however clumsy the attendant loader may be, the shooter is perfectly safe compared with outside hammer guns that are always liable to be loaded at full cock.

FOR PRICES AND FULL PARTICULARS APPLY TO:

JAMES WOODWARD & SONS,
EXPRESS GUN AND RIFLE MANUFACTURERS,
64, ST. JAMES'S STREET.
Manufactory—1, BLUE BALL YARD LONDON.



# FRASER'S

## PATENT SIDE LEVER EXPRESS SINGLE RIFLE.

**In strength and simplicity of lock mechanism equal to any Military Arm. It forms, when fitted with a barrel on our improved system of rifling, one of the most effective sporting weapons yet produced.**

**SIMPLE TO MANIPULATE, AND EASILY CLEANED.**

**Self-Cocking, Self-Extracting, and Safe**

**BARRELS BORED FROM THE SOLID OUT OF CRUCIBLE STEEL.**

**Perfect accuracy and flat trajectory. guaranteed.**

Attention is solicited to our new pattern of engraving, after pure Celtic designs, by Hubert W. Paton, Esq. This style of ornament is extremely handsome, and is admirably adapted for the decoration of high-class Guns and Rifles intended for presentation.

## SPECIALITIES.

**EXPRESS DOUBLE**

**AND**

**SINGLE RIFLES.**

**Fitted with Col. Davidson's Patent Telescopic Sights.**

**Suited for Sportsmen with Failing Vision.**

MINIATURE

**EXPRESS DOUBLE AND SINGLE RIFLES.**

**ROOK AND RABBIT RIFLES,**

**With Lyman and Beach Sights.**

**In ·220, ·295, ·300, ·320, and ·360 gauges.**

MINIATURE

**SINGLE EXPRESS.**

**Fraser Patent Action.**

**INTERCHANGEABLE BARRELS.**

## D. & J. FRASER,

**4, LEITH STREET TERRACE, EDINBURGH.**

**Patentees and Manufacturers of the Match Rifle adopted by the National Rifle Club of Scotland.**

WESTLEY RICHARDS and CO., LIMITED,
178, NEW BOND STREET, LONDON; and 82, HIGH STREET, BIRMINGHAM,
GUNMAKERS BY SPECIAL APPOINTMENT TO
H.R.H. the PRINCE of WALES, H.R.H. the DUKE of EDINBURGH, and H.R.H. the DUKE of CONNAUGHT.
MANUFACTURERS OF THE
WESTLEY RICHARDS PATENT HAMMERLESS GUN,
With Anson and Deeley's Lock and Cocking Arrangement and Patent Automatic Trigger and Tumbler Safety Bolts.

WESTLEY RICHARDS'
PATENT DOUBLE
HAMMERLESS EXPRESS RIFLES,
For Deer-Stalking or Large Game.
·400, ·450, ·500, and ·577.

Sole Manufacturers for the
DEELEY-EDGE-METFORD RIFLES,
MILITARY, MATCH, and SPORTING EXPRESS
DEELEY-EDGE ROOK RIFLES,
·320 OR ·380 BORES.
MINIATURE EXPRESS RIFLE, ·360 BORE.

As a Military Rifle the Deeley-Edge is unequalled. At the Wimbledon Meeting, July, 1883, the whole of the five prizes in the competition for the "Duke of Cambridge" prizes, and the whole of the five prizes in the competition for the "Bass" prizes, were won with these Rifles, besides numerous other prizes at the same meeting.

It has proved the most successful HAMMERLESS GUN yet invented. It has been in use over seven years, and some Thousands have been sold. It is easy to manipulate, perfect in form, and absolutely safe. Price from £25 to £42. Every Gun and Rifle made by us is carefully tested, and the Highest Possible Shooting guaranteed.

# IMPROVED BREECHLOADERS.

**LARGEST STOCK IN LONDON, BEST WORKMANSHIP, WITH LATEST IMPROVEMENTS.**

**Top and side lever, hammers below line of sight, fine Damascus or compressed steel barrels, choke bore, &c.**

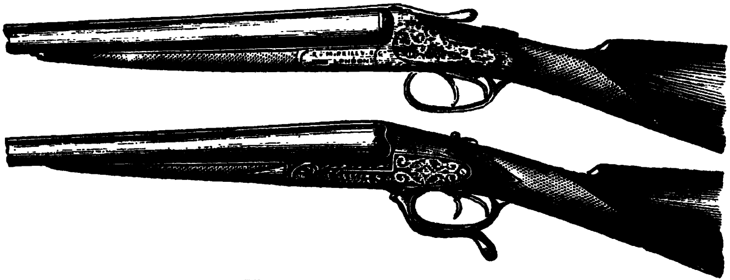
**Light 12-bores for Kynoch's brass cases mark 14, twelve wad.**

**Pairs of Guns and sets of three in same case ready as in stock, finished or made to order.**

## SPECIAL PIGEON GUNS,

**Of great power, Hurlingham weight, &c. Whitworth's Steel Tubes. Marvellous pattern. Trial at our private Shooting Grounds.**

# HAMMERLESS GUNS.



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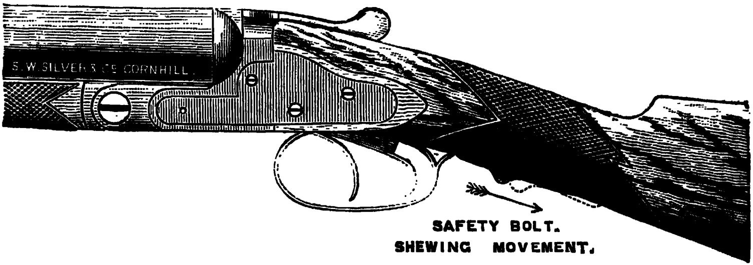
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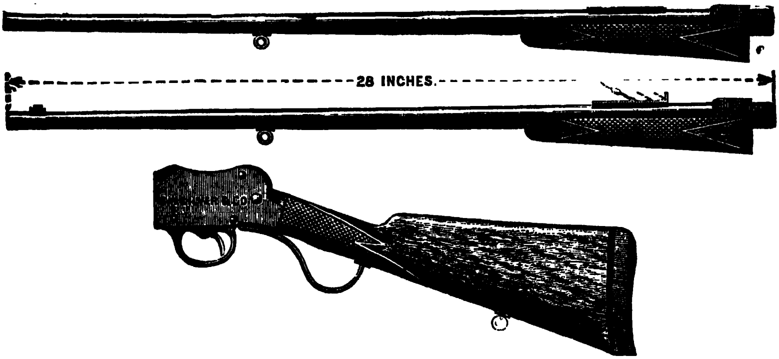

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## PATENT

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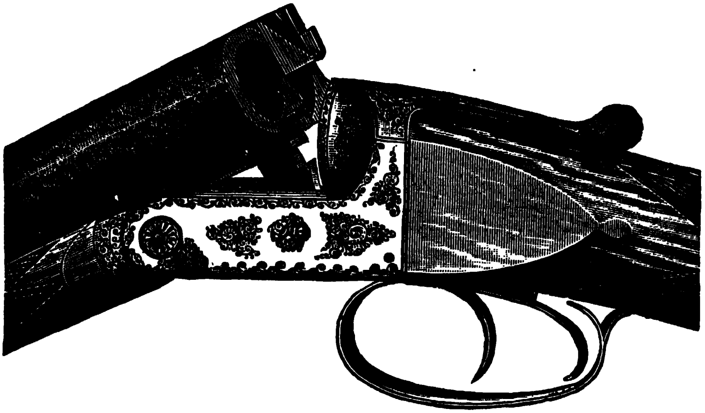

**The Editor of the "Field," in his review of the Gun, remarks:**

"During the last few weeks we have received for notice in 'The Modern Sportsman's Gun' several novelties which there has not hitherto been time or space to notice in the 'Field.' For the benefit, therefore, of those who do not see the book, we insert descriptions of them in our columns, commencing with the above Gun, which was brought to our notice by Mr. Leeson, of Ashford, in the shape of a beautifully designed and finished pigeon gun, built for a well-known performer at the traps. In this gun the chief novelty is the bolting of the top connection, which is usually carried out either by a snap-bolt, as in the Westley-Richards gun, or by a cross-bolt, as in the Greener treble-grip. In neither of these, however, is there any grip or draw, in which resides the great power of the 'double grip,' so well known to all modern shots; but in the new top grip, as introduced into Mr. Leeson's gun, an absolute grip is effected, either with or without a doll's head to assist it. On a careful inspection it will be seen that this action is full of merit, being exceedingly strong, working in all its parts very smoothly, and cocking the tumblers with remarkable ease. This last point is effected, partly by a careful adaptation of the levers, and partly by reducing the strength of the mainspring, and at the same time lengthening the throw of the tumbler, by which the breaking of the cap is insured; while, at the same time, the force required to open and cock the gun is greatly reduced. In our opinion, this action is by far the more pleasant to handle than any barrel cocker we have yet seen, and we have proved by experiment that the cap is well broken by the reduced spring. The strikers are separate from the tumblers, in which respect they differ from the ordinary Anson and Deeley gun, being let in from the front and provided with shoulders, which intercept the gas escape to a very great extent. The barrels are of Siemen's steel. We congratulate Mr. Leeson on both the principle and workmanship of the gun exhibited to us."

It will be seen from the above excellent authority that this action is the strongest made, and therefore especially suitable for Rifles when large charges are used, and is equally adaptable for guns and rifles with or without hammers.

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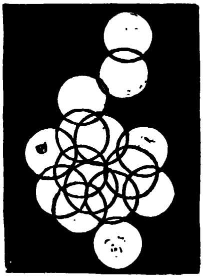

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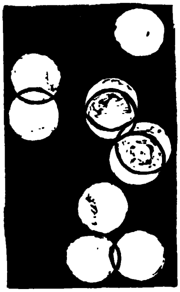

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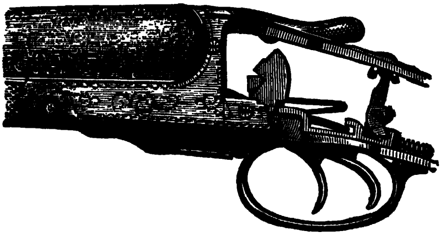

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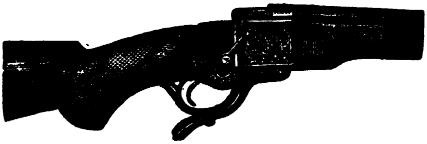

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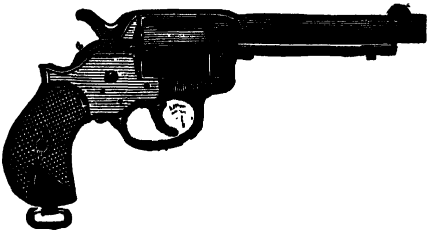

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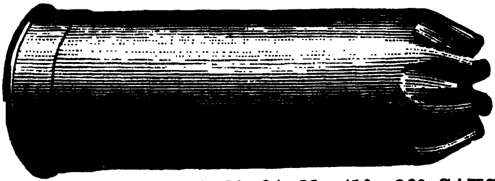

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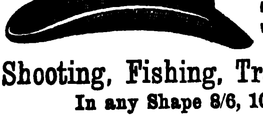

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